

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

501.38383X00

Filed: March 31, 2000

U.S. APPLICATION NO. (If known, see 37 CFR 1.51)

09/509768

**TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371**

INTERNATIONAL APPLICATION NO.
PCT/JP99/04790

INTERNATIONAL FILING DATE
03 September 1999 (3.09.99)

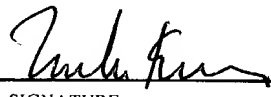
PRIORITY DATE CLAIMED

TITLE OF INVENTION
ROTATING ELECTRIC MACHINE AND COOLING METHOD THEREOF

APPLICANT(S) FOR DO/EO/US
See Attachment 1

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
 2. ☐ This is a **SECOND or SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
 3. ☐ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(I).
 4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
 5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
 6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
 7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
 8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
 9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
 10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).
- Items 11. to 16. below concern document(s) or information included:**
11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
 12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
 13. ☐ A FIRST preliminary amendment.
☐ A SECOND or SUBSEQUENT preliminary amendment.
 14. ☐ A substitute specification.
 15. ☒ A change of power of attorney and/or address letter.
 16. ☒ Other items or information: PCT REQUEST FORM
INTERNATIONAL EXAMINATION REPORT W/ AMENDMENT UNDER ART. 34
PTO FORM 1449 W/REFS.

U.S. APPLICATION NO. (if known see 31 CFR 1.5) 09/509768		INTERNATIONAL APPLICATION NO. PCT/JP99/04790		ATTORNEY'S DOCKET NUMBER 501 38383X00	
17. <input checked="" type="checkbox"/> The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO \$970.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO \$840.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$760.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$670.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) \$96.00 ENTER APPROPRIATE BASIC FEE AMOUNT =				CALCULATIONS PTO USE ONLY	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(c)).				\$ 0.00	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	19 -20 =	0	X \$18.00	\$ 0.00	
Independent claims	9 -3 =	6	X \$78.00	\$ 468.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+\$260.00	\$ 260.00	
TOTAL OF ABOVE CALCULATIONS =				\$ 1,568.00	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).				\$ 0.00	
SUBTOTAL =				\$ 1,568.00	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$ 0.00	
TOTAL NATIONAL FEE =				\$ 1,568.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				\$ 40.00	
TOTAL FEES ENCLOSED =				\$ 1,608.00	
				Amount to be:	\$
				refunded	
				charged	\$
a. <input checked="" type="checkbox"/> A check in the amount of \$ <u>1,608.00</u> to cover the above fees is enclosed.					
b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.					
c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>01-2135</u> . A duplicate copy of this sheet is enclosed.					
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.					
SEND ALL CORRESPONDENCE TO Melvin Kraus Antonelli, Terry, Stout & Kraus, LLP 1300 North Seventeenth Street Suite 1800 Arlington, VA 22209				 SIGNATURE Melvin Kraus NAME <u>22,466</u> REGISTRATION NUMBER	

09/509768

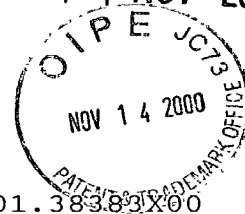
422 Rec'd PCT/PTO 31 MAR 2000

Addendum

Attachment 1

IDE, Kazumasa; HATTORI, Kenichi; KUMURA, Akiyoshi; YAMASHINA, Mitsunori; SONOBE, Tadashi; SEMBA, Akitomi; SATO, Junji; and SHIOBARA, Ryoichi

414 Rec'd PCT/PTO 14 NOV 2000 PCT



501.38383X00

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): IDE, et al
Serial No.: 09/509,768
Filed: March 31, 2000
For: ROTATING ELECTRIC MACHINE AND COOLING METHOD
THEREOF
Group:
Examiner:

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

November 14, 2000

Sir:

The following preliminary amendments and remarks are respectfully submitted in connection with the above-identified application.

IN THE SPECIFICATION:

Please replace the original specification with the attached Substitute Specification.

IN THE CLAIMS:

Please amend the claims as follows:

1. (amended) A rotating electric machine comprising:
a plurality of ventilating passages formed between a stator frame and a stator iron core;

a cooler provided at least in one ventilating passage,
[communicated to] communicating with a central portion [in the
axial direction] of said stator iron core, of said plurality
of ventilating passages;

a booster for boosting a coolant; and

a ventilating circuit in which the coolant boosted by
said booster, being cooled by said cooler, [and] is allowed to
flow to said central portion [in the axial direction] of said
stator iron core in the direction from the outer peripheral
side to the inner peripheral side of said stator iron core via
said ventilating passage [communicated to] which communicates
with said central portion [in the axial direction] of said
stator iron core.

2. (amended) A rotating electric machine comprising:
a plurality of ventilating passages formed between a
stator frame and a stator iron core;

coolers provided in said plurality of said ventilating
passages;

a booster for boosting a coolant; and

a ventilating circuit in which part or all of the coolant
cooled by one of said coolers and boosted by said booster is
further cooled by another of said coolers, and is allowed to
flow to a central portion [in the axial direction] of said
stator iron core in the direction from the outer peripheral
side to the inner peripheral side of said stator iron core at

least via one ventilating passage, [communicated to] communicating with said central portion [in the axial direction] of said stator iron core, of said plurality of ventilating passages.

3. (amended) A rotating electric machine comprising:
a plurality of ventilating passages formed between a stator frame and a stator iron core;

coolers provided in said plurality of ventilating passages;

a fan for boosting a coolant;

a first ventilating circuit in which the coolant boosted by said fan is introduced from the inner peripheral side of said stator iron core into some of said ventilating passages and is cooled by some of said coolers; and

a second ventilating circuit in which the coolant boosted by said fan is cooled by some of said coolers and is allowed to flow to said stator iron core in the direction from the outer peripheral side to the inner peripheral side of said stator iron core via some of said ventilating passages;

wherein at least one ventilating passage, [communicated to] communicating with a central portion [in the axial direction] of said stator iron core, of said plurality of ventilating passages, constitutes part of said second ventilating circuit.

4. (amended) A rotating electric machine comprising:
a plurality of ventilating passages formed between a
stator frame and a stator iron core;
coolers provided in said plurality of ventilating
passages;
a fan for boosting the coolant;
a first ventilating circuit in which the coolant boosted
by said fan is introduced from the inner peripheral side of
said stator iron core to some of said ventilating passages and
is cooled by some of said coolers; and
a second ventilating circuit in which the coolant boosted
by said fan and branched from said first ventilating circuit
is cooled by some of said coolers, and is allowed to flow to
said stator iron core in the direction from the outer
peripheral side to the inner peripheral side of said stator
iron core;
wherein at least one ventilating passage, [communicated
to] communicating with a central portion [in the axial
direction] of said stator iron core, of said plurality of
ventilating passages, constitutes part of said second
ventilating circuit.

5. (amended) A rotating electric machine in which the
inside of said machine is cooled by a coolant enclosed
therein, comprising:
a plurality of ventilating passages formed between a

stator frame and a stator iron core;

coolers provided in said plurality of ventilating passages;

a fan for boosting a coolant;

a first ventilating circuit in which the coolant boosted by said fan is introduced from the inner peripheral side of said stator iron core into some of said ventilating passages and is cooled by some of said coolers; and

a second ventilating circuit in which the coolant boosted by said fan is cooled by some of said coolers and is allowed to flow to said stator iron core in the direction from the outer peripheral side to the inner peripheral side of said stator iron core via some of said, ventilating passages;

wherein at least one ventilating passage, [communicated to] communicating with a central portion [in the axial direction] of said stator iron core, of said plurality of ventilating passages, constitutes part of said second ventilating circuit.

6. (amended) A rotating electric machine in which the inside of said machine is cooled by atmospheric air sucked from outside said machine, comprising:

a plurality of ventilating passages formed between a stator frame and a stator iron core;

a fan for boosting a coolant;

a first ventilating circuit in which [the] atmospheric

air boosted by said fan is introduced from the inner peripheral side of said stator iron core into some of said ventilating passages; and

a second ventilating circuit in which [the] atmospheric air boosted by said fan is allowed to flow to said stator iron core in [the] a direction from the outer peripheral side to the inner peripheral side of said stator iron core via some of said ventilating passages;

wherein a cooler is provided at least in one ventilating passage, which constitutes part of said second ventilating circuit and which [is communicated to] communicates with a central portion [in the axial direction] of said stator iron core, of said plurality of ventilating passages.

7. (amended) A rotating electric machine in which the inside of said machine is cooled by atmospheric air sucked from outside said machine, comprising:

a plurality of ventilating passages formed between a stator frame and a stator iron core;

a fan for boosting a coolant;

a first ventilating circuit in which [the] atmospheric air boosted by said fan is introduced from the inner peripheral side of said stator iron core into some of said ventilating passages; and

a second ventilating circuit in which [the] atmospheric air boosted by said fan is allowed to flow to said stator iron

core in [the] a direction from the outer peripheral side to the inner peripheral side of said stator iron core via some of said ventilating passages;

wherein a cooler is provided at least on the way of a ventilating passage for communicating an atmospheric air suction hole to one ventilating passage, which constitutes part of said second ventilating circuit and which [is communicates to] communicates with a central portion [in the axial direction] of said stator iron core, of said plurality of ventilating passages.

9. (amended) A rotating electric machine comprising:
a plurality of ventilating passages formed between a
stator frame and a stator iron core;

coolers provided in said plurality of ventilating passages;

a fan for boosting a coolant;

a first ventilating circuit in which the coolant boosted by said fan is introduced from the inner peripheral side of said stator iron core into some of said ventilating passages and is cooled by some of said coolers; and

a second ventilating circuit in which the coolant boosted by said fan is cooled by some of said coolers and is allowed to flow to said stator iron core in [the] a direction from the outer peripheral side to the inner peripheral side of said stator iron core via some of said ventilating passages;

wherein at least one ventilating passage, [communicated to] communicating with a central portion [in the axial direction] of said stator iron core, of said plurality of ventilating passages, constitutes part of said second ventilating circuit; and

said coolers provided in said first ventilating circuit and said coolers in said second ventilating circuit are opposed to each other with a rotating shaft [put] disposed therebetween.

10. (amended) A rotating electric machine according to any one of claims 1 to 7 and 9, wherein said stator iron core has a plurality of ventilating ducts which continuously extend in the radial direction and which are arranged in the axial direction; and wherein

axial intervals of those[,] ventilating ducts positioned at said central portion [in the axial direction] of said stator iron core[, of said ventilating ducts] are smaller than axial intervals of those[,] ventilating ducts positioned at the other portion of said stator iron core[, of said ventilating ducts].

11. (amended) A rotating electric machine according to any one of claims 3 to 7 and 9, wherein said stator iron core has a plurality of ventilating ducts which continuously extend in the radial direction and which are arranged in the axial

direction; and wherein

axial intervals between those[, ventilating constituting part of said second ventilating circuit[, of said ventilating ducts] are smaller than axial intervals between those[, ventilating ducts constituting part of said second ventilating circuit[, of said ventilating ducts].

Claim 12, line 7, delete "in the axial direction".

IN THE ABSTRACT OF THE DISCLOSURE:

Please replace the original abstract with the following new abstract:

--ABSTRACT

A rotating electric machine exhibits a substantially level axial temperature rise distribution by supplying a coolant which is sufficiently cooled to a central portion of an iron core which is most distant from each of the axial ends of the iron core. A plurality of ventilating passages, which continuously extend in the peripheral direction, are provided in the axial direction between a stator frame and a stator iron core, and coolers are provided in the ventilating passages. A coolant boosted by a booster is cooled by the coolers and is allowed to flow to a central portion of the stator iron core in the direction from the outer peripheral side to the inner peripheral side of the stator iron core via ventilating passages which communicate with the central portion of the stator iron core.--

REMARKS

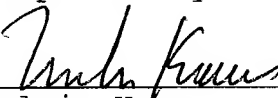
The specification has been amended to correct errors of a typographical and grammatical nature. Due to the excessive corrections thereto, applicants submit herewith a Substitute Specification, along with a marked-up copy of the original specification for the Examiner's convenience. Applicants submit that the substitute specification includes no new matter. Therefore, entry of the Substitute Specification is respectfully requested.

The claims have also been amended to more clearly describe the features of the present invention, and the abstract has been replaced by a new abstract, while correcting errors of a grammatical nature.

Entry of the preliminary amendments and examination of the application is respectfully requested.

To the extent necessary, applicant's petition for an extension of time under 37 CFR 1.136. Please charge any shortage in the fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account No. 01-2135 (501.38383X00) and please credit any excess fees to such deposit account.

Respectfully submitted,



Melvin Kraus
Registration No. 22,466
ANTONELLI, TERRY, STOUT & KRAUS, LLP

MK/DRA/cee
Attachments
(703) 312-6600

SUBSTITUTE SPECIFICATION

DESCRIPTION

ROTATING ELECTRIC MACHINE AND COOLING METHOD THEREOF

Technical Field

The present invention relates to a rotating electric
5 machine in which a cooler for cooling a coolant is provided,
as well as to a method of cooling a rotating electric vehicle.

Background of the Invention

A rotating electric machine in which a cooler for cooling
a coolant is provided has been described, for example, in
10 Japanese Patent Laid-open Nos. Hei 7-177705 and Hei 10-146022.
The rotating electric machine described in these documents is
configured such that a space between a stator frame and a
stator iron core is partitioned into a low temperature gas
chamber, to which a coolant at a low temperature is supplied,
15 and a high temperature gas chamber, in which the heated
coolant flows. A plurality of coolers distributed in the
axial direction are provided in a foundation pit under the
rotating electric machine, whereby the coolant cooled by the
plurality of coolers and boosted by a ventilating fan is
20 introduced to various heat sources, such as the iron core and
the coils, via the low temperature gas chamber, and the
coolant which has been used for cooling the heat sources is
returned to the coolers via the high temperature gas chamber.

The above-described rotating electric machine, however,
25 has a problem. Since the coolant which has passed through one

or two or more of the heat sources is then introduced to a central portion of the iron core, the temperature of the coolant is raised before the coolant reaches the central portion of the iron core. Accordingly, for the above-described rotating electric machine, if a thermal load generated from the heat sources, such as the iron core and coils, becomes large with an increase in the generation capacity or in the loss density, the cooling effect of the coolant introduced to the central portion of the iron core is significantly degraded. As a result, in the above-described rotating electric machine, there is a possibility that local heat generation will occur in a gap between the stator iron core and a rotor iron core, thereby to increase the thermal oscillation stroke of the rotor due to uneven thermal expansion of the rotor in the axial direction.

To solve the above-described problem, there may be considered a method of increasing the amount of the coolant or optimizing the distribution of the amounts of the coolant components supplied to respective ventilating passages by adjusting the ventilating resistance; however, according to the former method, the ventilation loss of the coolant caused upon boosting the coolant by the fan becomes larger, to increase the total loss in the coolant; and, according to the latter method, since the ventilation resistance must be adjusted while the desired electric and mechanical characteristics are satisfied in a limited space, it is difficult to optimize the distribution of the coolant

components supplied to the respective ventilating passages.

Summary of the Invention

An object of the present invention is to provide a rotating electric machine which is capable of exhibiting a level axial temperature rise distribution, and a cooling method thereof.

The basic feature of the present invention is to supply a coolant, which is sufficiently cooled, to a central portion of an iron core which is most distant from both axial ends of the iron core. To realize this feature of the present invention, a plurality of ventilating passages, which continuously extend in the peripheral direction, are provided in the axial direction between a stator frame and a stator iron core, and coolers are provided in at least those passages, which communicate with the central portion of the iron core, of the plurality of ventilating passages formed in the axial direction, wherein the coolant boosted by a booster is cooled by the coolers and is allowed to flow to the central portion of the iron core in the direction from the outer peripheral side to the inner peripheral side of the iron core via the ventilating passages.

If an even number of ventilating passages are provided, two to four of the ventilating passages, which are located on the central side, constitute the ventilating passages which communicate with the central portion of the iron core. If an odd number of ventilating passages are provided, one to three of the ventilating passages, which are located on the central

side, constitute the ventilating passages which communicate with the central portion of the iron core. The number of the ventilating passages is dependent on the capacity of the rotating electric machine. For example, for a generator having a generation capacity of 100 MW class, at least three ventilating passages are provided, and for a generator having a generation capacity of 350 MW class or more, seven to ten or more ventilating passages are provided.

According to the above feature of the present invention, it is possible to level the axial temperature rise distribution in the machine. In particular, the above feature is effective in a rotating electric machine in which the axial length is long and air is used as a coolant, for example, an air-cooled generator having a large capacity. Air which is larger in viscosity than hydrogen exhibits a high ventilating resistance when it flows in a generator, to thereby cause a temperature rise. The longer the ventilating distance of air, the larger the ventilating resistance will be. As a result, for a generator which is longer in axial length and larger in capacity, the temperature rise of the air becomes significantly larger, and the amount of the air supplied to the central portion of an iron core becomes smaller.

Accordingly, a small amount of air whose temperature is raised is supplied to the central portion of the iron core which is most distant from both the axial ends of the iron core, with a result that there occurs a difference in temperature between each of the axial ends of the iron core

and the central portion of the iron core. According to the present invention, it is possible to supply a coolant which is sufficiently cooled to the central portion of the iron core, however, it is also possible to suppress the temperature rise of the central portion of the iron core to an allowable value or less, and, hence, to level the axial temperature rise distribution in the machine.

The leveling of the axial temperature rise distribution in the machine means that the temperature rise of the central portion of the iron core is suppressed to an allowable value or less, to reduce the difference in temperature between each of the axial ends of the iron core and the central portion of the iron core. Accordingly, there is no variation in the axial temperature rise distribution in the machine.

Brief Description of Drawings

Fig. 1 is a perspective view, with parts partially cutaway, showing the external appearance and inner configuration of a turbine generator according to a first embodiment of the present invention;

Fig. 2 is a plan view, as seen in the direction shown by an arrow II of Fig. 1, showing the external configuration of the turbine generator;

Fig. 3 is a plan view, as seen in the direction shown by an arrow III of Fig. 2, showing the external configuration of the turbine generator;

Fig. 4 is a sectional view taken on line IV-IV of Fig. 1, showing the inner structure of a portion, positioned under a

rotating shaft, of the turbine generator;

Fig. 5 is a perspective view showing the external configuration of a turbine generator according to a second embodiment of the present invention;

5 Fig. 6 is a sectional view taken on line VI-VI of Fig. 5, showing the inner structure of a portion, positioned over a rotating shaft, of the turbine generator;

Fig. 7 is a sectional view showing the inner structure of a portion, positioned over a rotating shaft, of a turbine generator according to a third embodiment;

Fig. 8 is a sectional view showing the inner structure of a portion, positioned over a rotating shaft, of a turbine generator according to a fourth embodiment of the present invention;

15 Fig. 9 is a sectional view showing the inner structure of a portion, positioned under a rotating shaft, of a turbine generator according to a fifth embodiment of the present invention;

Fig. 10 is a front view showing the external configuration of a turbine generator according to a sixth embodiment of the present invention;

Fig. 11 is a side view, as seen in the direction shown by an arrow XI of Fig. 10, showing the external configuration of the turbine generator;

25 Fig. 12 is a sectional top view taken on line XII-XII of Fig. 11, showing the inner configuration of the turbine generator;

Fig. 13 is a sectional view showing the inner configuration of a portion, positioned under a rotating shaft, of a turbine generator according to a seventh embodiment of the present invention; and

5 Fig. 14 is a sectional view showing the inner configuration of a portion, positioned under a rotating shaft, of a turbine generator according to an eighth embodiment of the present invention.

Best Mode for Carrying Out the Invention

10 Hereinafter, various embodiments of the present invention will be described with reference to the drawings.

(First Embodiment)

 Figs. 1 to 4 show the configuration of a turbine generator according to a first embodiment of the present invention. The turbine generator in this embodiment is of an enclosed type (or a full-closed type) in which the inside of the generator is cooled with a coolant enclosed in the generator. In these figures, reference numeral 1 designates a stator frame. A cylindrical stator iron core 2 is provided inside the stator frame 1. A plurality of slots 3, which continuously extend in the axial direction, are formed in an inner peripheral portion of the stator iron core 2 in such a manner as to extend in the peripheral direction. Stator coils 4 are enclosed in the slots 3. A plurality of ventilating ducts 5, which continuously extending the radial direction, are formed in the stator iron core 2 in such a manner as to be spaced from each other at equal intervals in the axial

direction.

A rotor iron core 7 is provided on the inner peripheral side of the stator iron core 2 and is disposed with an air gap 6 between the rotor iron core 7 and the stator iron core 2. A plurality of slots (not shown), which continuously extend in the axial direction, are formed in an outer peripheral portion of the rotor iron core 7 in such a manner as to extend in the peripheral direction. Rotor coils (not shown) are enclosed in the slots of the rotor iron core 7. Cylindrical retaining rings 8 for pressing both ends of the rotor coils are provided at both ends of the rotor iron core 7. A rotating shaft 9 is provided integrally with the rotor iron core 7 in such a manner as to extend in the axial direction along the central axis of the rotor iron core 7.

Annular end brackets 10 functioning as block members are provided at both axial ends of the stator frame 1. A bearing apparatus 11 for rotatably supporting the rotating shaft 9 is provided on the inner peripheral side of each end bracket 10. A current collector 12 for supplying power to the rotor coils during rotation is provided at one end (outside the bearing apparatus 11) of the rotating shaft 9. The current collector 12 is configured to electrically connect the stator side to the rotor side by bringing carbon brushes into press-contact with a current-collecting ring provided at the one end (outside the bearing apparatus 11) of the rotating shaft 9. A connecting portion connected to a turbine, serving as a driving source for rotating the generator, is formed at the

other end (outside the bearing apparatus 11) of the rotating shaft 9.

Fans 13 for boosting a coolant enclosed in the generator and circulating it in the generator are provided at both ends (inside the bearing apparatuses 11) of the rotating shaft 9. While the fans 13 are used as boosters for boosting the coolant in this embodiment, other types of boosters may be used. The fans 13 provided at both ends (outside the bearing apparatuses 11) of the rotating shaft 9 are right-left symmetrical with respect to a center line 14. The center line 14 is a bisector which crosses the rotating shaft 9 at right angles at such a position as to equally divide the distance between the end brackets 10 into right-left symmetric parts.

Terminals 15 for three-phases of voltage are provided on the upper surface of the stator frame 1 in such a manner as to project upwardly therefrom. The terminals 15 are used for taking generated power out of the stator coils 4, which are electrically connected to the terminals 15. Hoisting accessories 16 are provided on the front surface of the stator frame 1 at two positions and on the back surface thereof at two positions. For example, when installed in a foundation pit 17, the generator main body is hoisted by a crane via wires fastened to the hoisting accessories 16.

Ventilating passages 18a to 18g, which continuously extend in the peripheral direction, are provided between the stator frame 1 and the stator iron core 2 in parallel to each other in the axial direction. The ventilating passages 18a to

18g are formed by a plurality of annular partition plates 19 for partitioning the space between the stator frame 1 and the stator iron core 2 in the axial direction, the inner surface of the stator frame 1, and the outer peripheral surface of the stator iron core 2, and they communicate with the ventilating ducts 5 in the stator iron core 2. The ventilating passages 18a to 18g are right-left symmetrical with respect to the center line 14.

Ventilating ducts 22a to 22c, extending in the axial direction, are provided on the back surface of the stator frame 1 in parallel with each other in a direction perpendicular to the axial direction. The ventilating ducts 22a and 22c form ventilating passages 20 continuously extending in the axial direction. The ventilating passages 20 communicate with the ventilating passages 18b, 18d, and 18f. The ventilating duct 22b forms a ventilating passage 21 continuously extending in the axial direction. The ventilating passage 21 communicates with the ventilating passages 18a, 18c, 18e, and 18g.

Ventilating passages 23 to 26, which continuously extend in the radial direction, are provided between the stator iron core 2 and the end brackets 10. The ventilating passages 23 to 26 are formed by partitioning a space between the stator iron core 2 and the end bracket 10 annular partitioning plates 27 facing the outer peripheral side of the fan 13. The ventilating passages 23 and 24, each of which provides communication between the discharge side of the fan 13 and the

ventilating passage 20, are right-left symmetrical with respect to the center line 14. The ventilating passages 25 and 26, each of which provides communication between the suction side of the fan 13 and the ventilating passage 21, are
5 right-left symmetrical with respect to the center line 14.

Each of the ventilating passages 18a to 18g is provided with a cooler for cooling a coolant enclosed in the generator. The coolers 28a to 28g are arranged under the generator in such a manner as to be aligned in a row in the axial
10 direction. It should be noted that the coolers 28a to 28g also may be arranged on the upper portion of the generator. The coolers 28a to 28g are disposed so as to be right-left symmetrical with respect to the center line 14. A pipe line
15 29 for supplying cooling water and a pipe line 30 for discharging cooling water are connected to each of the coolers 28a to 28g. The coolers 28a to 28g are identical to each other in cooling capacity, but are different from each other in external size depending on the size of the ventilating
20 passage 18 on which the cooler is provided. In this embodiment, since the axial width of each of the ventilating passages 18b and 18f is smaller than that of each of the remaining ventilating passages, the axial width of each of the coolers 28b and 28f is made smaller than that of each of the remaining coolers.

25 A plurality of ventilating circuits configured by the above-described ventilating passages, etc. are formed in the generator. A first ventilating circuit 29, a second

ventilating circuit 30, and a third ventilating circuit 31 are formed on one side (left side in Fig. 4) the center line 14, and similarly three ventilating circuits are formed on the other side (right side in Fig. 4) relative to the center line 14. The three ventilating circuits formed on the one side from the center line 14 are right-left symmetrical relative to the three ventilating circuits formed on the other side from the center line 14. Further, the flow of a coolant and the temperature rise characteristic on the one side from the center line 14 are right-left symmetrical relative to those on the other side from the center line 14. Therefore, the configuration of the ventilating circuits and the flow of a coolant on only one side of the center line 14 will be described below.

The first ventilating circuit 29 is a closed loop designated by a solid arrow in Fig. 4, which extends from the discharge side of the fan 13 to the ventilating duct 5 via the air gap 6, further extends from the ventilating duct 5 to the cooler 28a via the ventilating passage 18a, and then extends from the cooler 28a to the suction side of the fan 13 via the ventilating passages 21 and 25. In the first ventilating circuit 29, heat sources giving heat to the ventilating passages 18a, air gap 6 and ventilating duct 5 are connected in series to the cooler 28a. The heat source giving heat to the air gap 6 and the ventilating passage 18a is the stator iron core 2 generating iron loss, and the heat sources giving heat to the ventilating duct 5 are the stator iron core 2

generating iron loss and the stator coils 4 generating copper loss.

The second ventilating circuit 30 is a closed loop designated by a dotted arrow in Fig. 4, which extends from the discharge side of the fan 13 to the cooler 28b via the ventilating passage 23, further extends from the cooler 28b to the cooler 28c via the ventilating passage 18b, ventilating duct 5, air gap 6, ventilating duct 5, and then ventilating passage 18c, and extends from the cooler 28c to the suction side of the fan 13 via the ventilating passages 21 and 25. In the second ventilating circuit 30, heat sources and the coolers are alternately arranged in series, and, more specifically, the heat sources giving heat to the ventilating passage 23, the cooler 28b, the heat sources giving heat to the ventilating passages 18b and 18c, air gap 6 and ventilating duct 5, and the cooler 28c are arranged in this order. The heat source giving heat to the air gap 6 and ventilating passages 18b and 18c is the stator iron core 2 generating iron loss, and the heat sources giving heat to the ventilating duct 5 and the ventilating passage 23 are the stator iron core 2 generating iron loss and the stator coils 4 generating copper loss.

The third ventilating circuit 31 is a closed loop designated by a dotted arrow in Fig. 4, which extends from the discharge side of the fan 13 to the cooler 28d via the ventilating passage 23, further extends from the cooler 28d to the cooler 28c via the ventilating passage 18d, ventilating

duct 5, air gap 6, ventilating duct 5, and ventilating passage 18c, and then extends from the cooler 28c to the suction side of the fan 13 via the ventilating passages 21 and 25. In the second ventilating circuit 30, heat sources and the coolers are alternately arranged in series, and more specifically, the heat sources giving heat to the ventilating passage 23, the cooler 28d, the heat sources giving heat to the ventilating passages 18d and 18c, air gap 6, and ventilating duct 5, and the cooler 28c are arranged in series in this order. The heat source giving heat to the air gap 6 and the ventilating passages 18d and 18c is the stator iron core 2 generating iron loss, and the heat sources giving heat to the ventilating duct 5 and the ventilating passage 23 are the stator iron core 2 generating iron loss and the stator coils 4 generating copper loss.

The flow of the coolant will be described below. The coolant enclosed in the generator, which is boosted by rotation of the rotating shaft 9, flows from the discharge side of the fan 13 to each ventilating circuit. In the ventilating circuit 29, the coolant boosted by the fan 13 flows axially in the air gap 6 to the ventilating duct 5 communicating with the ventilating passage 18a. The coolant which has reached the ventilating duct 5 communicating with the ventilating duct 18a flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18a while cooling the inside of the stator iron core 2 and the

stator coils 4. The coolant which has reached the ventilating passage 18a cools the outer peripheral side of the stator iron core 2 and flows in the ventilating passage 18a to the cooler 28a. The coolant which has reached the cooler 28a is cooled
5 by the cooler 28a and flows from the cooler 28a to the suction side of the fan 13 via the ventilating passages 21 and 25.

In the second ventilating circuit 30, the coolant boosted by the fan 13 flows radially in the ventilating passage 23 to the ventilating passage 20 while cooling the end portion of
10 the stator iron core 2 and the coil end portions of the stator coils 4. The coolant which has reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28b. The coolant which has reached the cooler 28b is cooled by the cooler 28b and flows in the ventilating passage
15 18b in the peripheral direction while cooling the outer peripheral portion of the stator iron core 2 and reaches the ventilating duct 5 communicating with the ventilating passage 18b. The coolant which has reached the ventilating duct 5 communicating with the ventilating passage 18b flows in the
20 ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4.

The coolant which has reached the air gap 6 flows axially
25 in the air gap 6 to the ventilating duct 5 communicating with the ventilating passage 18c while cooling the inner peripheral side of the stator iron core 2. The coolant which has reached

the ventilating duct 5 communicating with the ventilating passage 18c flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18c while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant which has reached the ventilating passage 18c cools the outer peripheral side of the stator iron core 2 and flows in the ventilating passage 18c to the cooler 28c. The coolant which has reached the cooler 28c is cooled by the cooler 28c, and flows from the cooler 28c to the suction side of the fan 13 via the ventilating passages 21 and 25.

In the third ventilating circuit 31, the coolant boosted by the fan 13 flows radially in the ventilating passage 23 to the ventilating passage 20 while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant which has reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28d. The coolant which has reached the cooler 28d is cooled by the cooler 28d and flows in the ventilating passage 18d in the peripheral direction while cooling the outer peripheral side of the stator iron core 2 and reaches the ventilating duct 5 communicating with the ventilating passage 18d. The coolant which has reached the ventilating duct 5 communicating with the ventilating passage 18d flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air

gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4.

The coolant which has reached the air gap 6 flows axially in the air gap to the ventilating duct 5 communicating with the ventilating passage 18c while cooling the inner peripheral side of the stator iron core 2. The coolant which has reached the ventilating duct 5 communicating with the ventilating passage 18c flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18c while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant which has reached the ventilating passage 18c cools the outer peripheral side of the stator iron core 2 and flows in the ventilating passage 18c to the cooler 28c. The coolant which has reached the cooler 28c is cooled by the cooler 28c, and flows from the cooler 28c to the suction side of the fan 13 via the ventilating passages 21 and 25.

According to the embodiment configured as described above, the coolant boosted by the fan 13 is introduced to the ventilating passage 18d positioned at the central portion of the stator iron core 2, being cooled by the cooler 28d, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2, so that the coolant sufficiently cooled by the cooler can be supplied to the central portion of the stator iron core 2.

Accordingly, the central portion of the stator iron core

2 at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest can be cooled by the coolant, which is sufficiently cooled by the cooler, and thereby local heat generation in the air gap 6 can be suppressed. This makes it possible to level the axial temperature rise distribution in the generator and hence to suppress the thermal oscillation stroke of the rotor.

(Second Embodiment)

Figs. 5 and 6 show a configuration of a turbine generator according to a second embodiment. The turbine generator in this embodiment is of an enclosed type (or a full-closed type) like the turbine generator in the first embodiment, but is shorter in axial length (or smaller in generation capacity) than the turbine generator in the first embodiment. Further, the turbine generator in this embodiment is configured such that the coolers 28 and the ventilating passages 20 and 21 provided in the lower portion of the generator in the first embodiment are provided in an upper portion of the generator.

Ventilating passages 18a to 18d, which continuously extend in the peripheral direction, are provided between a stator frame 1 and a stator iron core 2 in parallel with each other in the axial direction. The ventilating passages 18b and 18c are in communication with a ventilating passage 20, and the ventilating passages 18a and 18d are in communication with a ventilating passage 21. Coolers 28a and 28d are provided in the ventilating passage 21 in such a manner as to

be right-left symmetrical with respect to a center line 14, and coolers 28b and 28c are provided in the ventilating passage 20 in such a manner as to be right-left symmetrical with respect to the center line 14. The coolers 28a to 28d are aligned in a row in the axial direction.

The coolers 28b and 28c are smaller in size, that is, have a smaller cooling capacity than the coolers 28a and 28d. One reason for this is that the coolers 28b and 28c are used for cooling part of a coolant which has been cooled by the coolers 28a and 28d, and therefore, it is sufficient for the coolers 28b and 28c to be smaller in cooling capacity than the coolers 28a and 28d. This is advantageous in terms of cooling efficiency. Another reason is that, since the ventilating passage 20 in which the coolers 28b and 28c are provided is smaller than the ventilating passage 21 in which the coolers 28a and 28d are provided, the sizes of the coolers 28b and 28c must be made smaller those of the coolers 28a and 28d. It should be noted that the coolers 28a to 28d may be arranged in the lower portion of the generator.

The other features of this embodiment are the same as those of the first embodiment, and therefore, a description thereof is omitted. In addition, since the ventilating passages and coolers are respectively right-left symmetrical with respect to the center line 14, and also the flow of a coolant and the temperature rise characteristic are respectively right-left symmetrical with respect to the center line 14, the configuration on only one side of the center line

14 will be described below.

The flow of a coolant will be described. When a fan 13 is rotated along with rotation of a rotating shaft 9, a coolant enclosed in the generator is boosted and is allowed to flow in respective ventilating passages. The coolant discharged on the discharge side of the fan 13 is branched into one component on a ventilating passage 23 side and another component on an air gap 6 side. The coolant component branched on the air gap 6 side flows in an air gap 6 to a ventilating duct 5 communicating with the ventilating passage 18a while cooling the inner peripheral side of the stator iron core 2.

The coolant component which has reached the ventilating duct 5 communicating with the ventilating passage 18a flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18a while cooling the inside of the stator iron core 2 and stator coils 4. The coolant component which has reached the ventilating passage 18a cools the outer peripheral side of the stator iron core 2 and flows from the ventilating passage 18a to the cooler 28a via the ventilating passage 21. The coolant component which has reached the cooler 28a is cooled by the cooler 28a and flows from the cooler 28a to the suction side of the fan 13 via the ventilating passage 25.

The coolant component branched on the ventilating passage 23 side flows radially in a ventilating passage 23 to

the ventilating passage 20 while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant component which has reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28b. The coolant component which has reached the cooler 28b is cooled by the cooler 28b, and flows from the cooler 28b to the ventilating passage 18b. The coolant component which has reached the ventilating passage 18b cools the outer peripheral side of the stator iron core 2, and flows in the ventilating passage 18b to the ventilating duct 5 communicating with the ventilating passage 18b.

The coolant component which has reached the ventilating duct 5 communicating with the ventilating passage 18b flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component which has reached the air gap 6 flows axially in the air gap 6 to the ventilating duct 5 communicating with the ventilating passage 18a while cooling the inner peripheral side of the stator iron core 2. The coolant component which has reached the ventilating duct 5 communicating with the ventilating passage 18a flows in the ventilating ducts 5 together with the above-described coolant component which has been branched from the discharge side of the fan 13 onto the air gap 6 side.

According to this embodiment, part of the coolant cooled by the cooler 28a (or 28d) and boosted by the fan 13 is

branched; and, the coolant component thus branched is cooled by the cooler 28b (or 28c), being introduced to the ventilating passage 18b (or 18c) positioned at the central portion of the stator iron core 2, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2. Accordingly, it is possible to supply the coolant sufficiently cooled by the cooler, to the central portion in the axial direction of the stator iron core 2.

As a result, according to this embodiment, the central portion of the stator iron core 2 at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest can be cooled by the coolant, which is sufficiently cooled by the cooler, so that it is possible to suppress local heat generation in the air gap 6, and hence to level the axial temperature rise distribution in the generator.

(Third Embodiment)

Fig. 7 shows a configuration of a turbine generator according to a third embodiment. This embodiment is a variation of the second embodiment, characterized in that the axial length of the turbine generator in this embodiment is longer than that of the turbine generator in the second embodiment. Ventilating passages 18a to 18e, which continuously extend in the peripheral direction, are provided between a stator frame 1 and a stator iron core 2 in parallel to each other in the axial direction. The ventilating passages 18a, 18b, 18d and 18e are in communication with a

ventilating passage 21, and the ventilating passage 18c is in communication with a ventilating passage 20. Coolers 28a and 28c are provided in the ventilating passage 21 in such a manner as to be right-left symmetrical with respect to a center line 14, and a cooler 28b is provided in the ventilating passage 20 at a communicating portion communicating with the ventilating passage 18c. The cooler 28b is smaller in size or cooling capacity than each of the coolers 28a and 28c.

The other features of this embodiment are the same as those of the second embodiment, and, therefore, a description thereof is omitted. In addition, since the ventilating passages and coolers are respectively right-left symmetrical with respect to the center line 14, and also the flow of coolant and the temperature rise characteristic are respectively right-left symmetrical with respect to the center line 14, the configuration on only one side of the center line 14 will be described below.

The flow of a coolant will be described. When a fan 13 is rotated along with rotation of a rotating shaft 9, a coolant enclosed in the generator is boosted and is allowed to flow in respective ventilating passages. The coolant discharged on the discharge side of the fan 13 is branched into one component on a ventilating passage 23 side and another component on an air gap 6 side. The coolant component branched on the air gap 6 side flows in an air gap 6 to ventilating ducts 5 communicating with the ventilating

passages 18a and 18b while cooling the inner peripheral side of the stator iron core 2.

The coolant component which has reached the ventilating ducts 5 communicating with the ventilating passages 18a and 18b flows in the ventilating ducts 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passages 18a and 18b, while cooling the inside of the stator iron core 2 and stator coils 4. The coolant component which has reached the ventilating passages 18a and 18b cools the outer peripheral side of the stator iron core 2 and flows from the ventilating passages 18a and 18b to the cooler 28a via the ventilating passage 21. The coolant component which has reached the cooler 28a is cooled by the cooler 28a and flows from the cooler 28a to the suction side of the fan 13 via a ventilating passage 25.

The coolant component branched on the ventilating passage 23 side flows radially in a ventilating passage 23 to the ventilating passage 20, while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant component which has reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28b. The coolant component which has reached the cooler 28b is cooled by the cooler 28b, and flows from the cooler 28b to the ventilating passage 18c. The coolant component which has reached the ventilating passage 18c cools the outer peripheral side of the stator iron core 2 and flows in the ventilating passage 18c to the ventilating

duct 5 communicating with the ventilating passage 18c.

The coolant component which has reached the ventilating duct 5 communicating with ventilating passage 18c flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6, while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component which has reached the air gap 6 flows axially in the air gap 6 to the ventilating ducts 5 communicating with the ventilating passages 18a and 18b, while cooling the inner peripheral side of the stator iron core 2. The coolant component which has reached the ventilating ducts 5 communicating with the ventilating passages 18a and 18b flows in the ventilating ducts 5 together with the above-described coolant component which has been branched from the discharge side of the fan 13 onto the air gap 6 side.

According to this embodiment, part of the coolant cooled by the cooler 28a (or 28c) and boosted by the fan 13 is branched; and, the coolant component thus branched is cooled by the cooler 28c, being introduced to the ventilating passage 18c positioned at the central portion of the stator iron core 2, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2. Accordingly, it is possible to supply the coolant, which is sufficiently cooled by the cooler, to the central portion of the stator iron core 2.

As a result, according to this embodiment, the central

portion of the stator iron core 2, at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest, can be cooled by the coolant, which is sufficiently cooled by the cooler, so that it is possible to suppress local heat generation in the air gap 6, and hence to level the axial temperature rise distribution in the generator.

(Fourth Embodiment)

Fig. 8 shows a configuration of a turbine generator according to a fourth embodiment. This embodiment is a combination of the second and third embodiments, characterized in that the axial length of the turbine generator in this embodiment is longer than that of the turbine generator in the third embodiment. Ventilating passages 18a to 18g, which continuously extend in the peripheral direction, are provided between a stator frame 1 and a stator iron core 2 in parallel to each other in the axial direction. The ventilating passages 18a, 18c, 18e and 18g are in communication with a ventilating passage 21, and the ventilating passage 18d is in communication with a ventilating passage 20. A ventilating passage 31 for connecting a ventilating passage 23 to the ventilating passage 18b and a ventilating passage 32 for connecting a ventilating passage 24 to the ventilating passage 18f are provided between the stator frame 1 and the stator iron core 2 in such a manner as to be right-left symmetrical with respect to a center line 14.

Coolers 28a and 28e are provided in the ventilating

passage 21 in such a manner as to be right-left symmetrical with respect to the center line 14. A cooler 28c is with provided in the ventilating passage 20 at a portion communicating with the ventilating passage 18d. The cooler 5 28c is smaller in size or cooling capacity than each of the coolers 28a and 28e. Coolers 28b and 28d are provided in the ventilating passage 31 in such a manner as to be right-left symmetrical with respect to the center line 14. The coolers 28b and 28d are each smaller in size or cooling capacity than 10 each of the coolers 28a and 28e.

The other features of this embodiment are the same as those of each of the second and third embodiments, and, therefore, a description thereof is omitted. In addition, since the ventilating passages and coolers are respectively 15 right-left symmetrical with respect to the center line 14, and also the flow of a coolant and the temperature rise characteristic are respectively right-left symmetrical with respect to the center line 14, the configuration on only one side of the center line 14 will be described below.

The flow of a coolant will be described. When a fan 13 20 is rotated along with rotation of a rotating shaft 9, a coolant enclosed in the generator is boosted and is allowed to flow in respective ventilating passages. The coolant discharged on the discharge side of the fan 13 is branched 25 into one component on a ventilating passage 23 side and another component on an air gap 6 side. The coolant component branched on the air gap 6 side flows in an air gap 6 to

ventilating ducts 5 communicating with the ventilating passages 18a and 18c while cooling the inner peripheral side of the stator iron core 2.

5 The coolant component which has reached the ventilating ducts 5 communicating with the ventilating passages 18a and 18c flows in the ventilating ducts 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passages 18a and 18c, while cooling the inside of the stator iron core 2 and stator coils 4. The coolant component which has reached the ventilating passages 18a and 18c cools the outer peripheral side of the stator iron core 2 and flows from the ventilating passages 18a and 18c to the cooler 28a via the ventilating passage 21. The coolant component which has reached the cooler 28a is cooled by the cooler 28a and flows from the cooler 28a to the suction side of the fan 13 via a ventilating passage 25.

20 The coolant component branched onto the ventilating passage 23 side flows radially in the ventilating passage 23 to the ventilating passages 20 and 31, while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant component which has reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28c. The coolant component which has reached the cooler 28c is cooled by the cooler 28c and flows from the cooler 28c to the ventilating passage 18d. The coolant component which has reached the ventilating passage 18d cools the outer peripheral side of the stator iron core 2

and flows in the ventilating passage 18d to the ventilating duct 5 communicating with the ventilating passage 18d.

5 The coolant component which has reached the ventilating duct 5 communicating with the ventilating passage 18d flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6, while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component which has reached the air gap 6 flows axially in the air gap 6 to 10 the ventilating ducts 5 communicating with the ventilating passages 18a and 18c while cooling the inner peripheral side of the stator iron core 2. The coolant component which has reached the ventilating ducts 5 communicating with the ventilating passages 18a and 18c flows in the ventilating 15 ducts 5 together with the above-described coolant component which has been branched from the discharge side of the fan 13 onto the air gap 6 side.

The coolant component which has reached the ventilating passage 31 flows axially in the ventilating passage 31 to the 20 cooler 28b. The coolant component which has reached the cooler 28b is cooled by the cooler 28b and flows from the cooler 28b to the ventilating passage 18b. The coolant component which has reached the ventilating passage 18b cools the outer peripheral side of the stator iron core 2 and flows 25 in the ventilating passage 18b to the ventilating duct 5 communicating with the ventilating passage 18b.

The coolant component which has reached the ventilating

duct 5 communicating with the ventilating passage 18b flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6, while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component which has reached the air gap 6 flows axially in the air gap 6 to the ventilating ducts 5 communicating with the ventilating passages 18a and 18c, while cooling the inner peripheral side of the stator iron core 2. The coolant component which has reached the ventilating ducts 5 communicating with the ventilating passages 18a and 18c flows in the ventilating ducts 5 together with the above-described coolant component which has been branched from the discharge side of the fan 13 onto the air gap 6 side.

According to this embodiment, part of the coolant cooled by the cooler 28a (or 28e) and boosted by the fan 13 is branched; and, the coolant component thus branched is cooled by the cooler 28c, being introduced to the ventilating passage 18d positioned at the central portion of the stator iron core 2, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2. Accordingly, it is possible to supply the coolant, which is sufficiently cooled by the cooler, to the central portion of the stator iron core 2.

As a result, according to this embodiment, the central portion of the stator iron core 2, at which the temperature of the supplied coolant tends to become highest and the amount of

the supplied coolant tends to become smallest, can be cooled by the coolant, which is sufficiently cooled by the cooler, so that it is possible to suppress local heat generation in the air gap 6, and hence to level the axial temperature rise distribution in the generator.

(Fifth Embodiment)

Fig. 9 shows a configuration of a turbine generator according to a fifth embodiment. This embodiment is an improvement over the first embodiment, which is effective in the case where the axial length of a stator iron core 2 becomes longer. In this embodiment, the axial interval between two adjacent ventilating ducts 5 provided in the stator iron core 2 is set at a large value in a first ventilating circuit 29 and is set at a small value in each of second and third ventilating circuits 30 and 31, which are larger in ventilating distance and thermal load than the first ventilating circuit 29. The remainder of the configuration is the same as that of the first embodiment, and therefore, a description thereof is omitted.

According to this embodiment, since the axial interval between two adjacent ventilating ducts 5 differs among the ventilating circuits 29, 30 and 31, it is possible to reduce the amount of coolant flowing in the first ventilating circuit 29, which is close to the fan 13, and thereby shorten the ventilating distance and increase the amount of coolant flowing in each of the second and third ventilating circuits 30 and 31, which are more distant from a fan 13 and thereby

longer in ventilating distance, and hence to improve the effect of cooling the central portion of the stator iron core 2 and its neighborhood.

Further, in this embodiment, since the axial interval
 5 between two adjacent ventilating ducts 5 differs among the ventilating circuits, it is possible to increase the cooling area of the central portion of the stator iron core 2 and its neighborhood by reducing the exposed area of the stator iron core 2 and stator coils 4 in the first ventilating circuit 29,
 10 which has a small thermal load, and by increasing the exposed area of the stator iron core 2 and the stator coils 4 in each of the second and third ventilating circuits 20 and 31, which have a large ventilating distance and thermal load, and hence to further improve the effect of cooling the central portion
 15 of the stator iron core 2 and its neighborhood.

It should be noted that this embodiment has been described as an improvement over the first embodiment however, the configuration of this embodiment may be applied to the other embodiments as well.

20 (Sixth Embodiment)

Figs. 10 to 12 show a configuration of a turbine generator according to a sixth embodiment. This embodiment is a variation of the first embodiment, in which the coolers 28 and the ventilating passages 20 and 21 provided in the lower
 25 portion of the generator in the first embodiment are provided in both a front portion (front surface side) and a rear portion (back surface side) of the generator. The coolers

placed in the vertical direction are aligned in a row in the axial direction on the front and back surfaces of the generator in such a manner as to project therefrom.

5 A cooler 28a provided in a ventilating passage 18a, a cooler 28c provided in a ventilating passage 18c, a cooler 28e provided in a ventilating passage 18e, and a cooler 28g provided in a ventilating passage 18g are arranged on the front portion of the generator in such a manner as to be right-left symmetrical with respect to a center line 14. A
10 ventilating passage 21 communicating with the ventilating passages 18a, 18c, 18e, and 18g is provided in the front portion of the generator.

A cooler 28b provided in a ventilating passage 18b, a cooler 28d provided in a ventilating passage 18d, and a cooler
15 28f provided in a ventilating passage 18f are arranged on the rear portion of the generator in such a manner as to be right-left symmetrical with respect to the center line 14. A ventilating passage 20 communicating with the ventilating passages 18b, 18d, and 18e is provided in the front portion of
20 the generator. The remainder of the configuration is the same as that of the first embodiment, and therefore, a description thereof is omitted.

According to this embodiment, the coolers 28a, 28c, 28e, and 28g are arranged on one side (front portion of the
25 generator) of a space between a stator frame 1 and a stator iron core 2, which are opposed to each other with respect to a rotating shaft 9, and the coolers 28b, 28d, and 28f are

arranged on the other side (rear portion of the generator) of the space. Accordingly, in the first, second, and third ventilating circuits 29, 30 and 31, a region in which a coolant flows from the inner peripheral side to the outer peripheral side of the stator iron core 2 and then passes through the coolers 28 can be formed in the front portion of the generator, and a region in which the coolant passes through the coolers 28 and then flows from the outer peripheral side to the inner peripheral side of the stator iron core 2 can be formed in the rear portion of the generator. As a result, it is possible to eliminate the intersection of the ventilating passages in which the coolant flows, and hence to reduce the ventilating resistance of the coolant. This makes it possible to increase the amount of the coolant to be supplied to the central portion of the stator iron core 2 and its neighborhood, and hence to further improve the effect of cooling the central portion of the stator iron core 2.

In this embodiment, description has been made by way of the example in which the coolers are arranged in both the front and rear portions of the generator; however, the same effect can be obtained even by adopting an example in which the coolers are arranged in both the upper and lower portions of the generator.

(Seventh Embodiment)

Fig. 13 shows a configuration of a turbine generator according to a seventh embodiment. The turbine generator in

this embodiment is of an open-type in which the inside of the generator is cooled by atmospheric air sucked in the generator. In the figure, reference numeral 50 designates a stator frame. A cylindrical stator iron core 51 is provided inside the stator frame 50. A plurality of slots, which continuously extend in the axial direction, are formed in an inner peripheral portion of the stator iron core 51 in such a manner as to extend in the peripheral direction. Stator coils 52 are enclosed in the slots. A plurality of ventilating ducts 53, which continuously extend in the radial direction, are formed in the stator iron core 51 in such a manner as to be spaced from each other at equal intervals in the axial direction.

A rotor iron core 55 is provided on the inner peripheral side of the stator iron core 51 with an air gap 54 disposed between the rotor iron core 55 and the stator iron core 51. A plurality of slots, which continuously extend in the axial direction, are formed in an outer peripheral portion of the rotor iron core 55 in such a manner as to extend in the peripheral direction, and rotor coils are enclosed in the slots. Cylindrical retaining rings 56 for pressing both ends of the rotor coils are provided at both ends of the rotor iron core 55. A rotating shaft 57 is provided integrally with the rotor iron core 55 in such a manner as to extend in the axial direction along the central axis of the rotor iron core 55.

Annular end brackets 58 functioning as block members are provided at both axial ends of the stator frame 50. A bearing

apparatus for rotatably supporting the rotating shaft 57 is provided on the inner peripheral side of each end bracket 58. A current collector for supplying power to the rotor coils during rotation is provided at one end (outside the bearing apparatus) of the rotating shaft 57. A connecting portion connected to a turbine serving as a driving source of the generator is formed at the other end (outside the bearing apparatus) of the rotating shaft 57.

Fans 59 for boosting a coolant sucked in the generator and circulating it in the generator are provided at both ends (inside the bearing apparatuses) of the rotating shaft 57. While the fans 59 are used as the boosters for boosting the coolant in this embodiment, other types of boosters may be used. The fans 59 provided at both ends (outside the bearing apparatuses) of the rotating shaft 57 are right-left symmetrical with respect to a center line 60. The center line 60 is a bisector which crosses the rotating shaft 57 at right angles at such a position as to equally divide the distance between the end brackets 58 into two right-left symmetric parts.

An air suction hole 61 for sucking atmospheric air in the generator is provided on the inner peripheral side of each end bracket 58 in such a manner as to face the fan 59. An air discharge hole 62 for discharging the atmospheric air which has been sucked in the generator to the outside of the generator is provided on the outer peripheral side of each end bracket 58.

Ventilating passages 63a to 63g, which continuously extend in the peripheral direction, are provided between the stator frame 50 and the stator iron core 51 in parallel with each other in the axial direction. The ventilating passages 63a to 63g are formed by a plurality of annular partition plates 64 for partitioning a space between the stator frame 50 and the stator iron core 51 in the axial direction, the inner surface of the stator frame 50, and the outer peripheral surface of the stator iron core 51, and are in communication with the ventilating ducts 53. The ventilating passages 63a to 63g are right-left symmetrical with respect to the center line 60.

Ventilating passages 65 and 66, which continuously extend in the radial direction, are provided between the stator iron core 51 and the end bracket 58. The ventilating passages 65 and 66 are right-left symmetrical with respect to the center line 60. Ventilating passages 67 and 68, which provide communication between the air suction holes 61 and the fans 59 and continuously extend in the axial direction, are provided between the end brackets 58 and the fans 59. The ventilating passages 67 and 68 are formed by partitioning spaces between the stator iron core 51 and the end brackets 58 by means of cylindrical partitioning plates 69, and are right-left symmetrical with respect to the center line 60.

A ventilating passage 70, which connects the ventilating passages 65 and 66 to the ventilating passages 63b, 63d and 63f and continuously extends in the axial direction, is

provided in the lower portion of the generator. A ventilating passage 71, which connects the air discharge holes 62 to the ventilating passages 63a, 63c, 63e and 63g and continuously extends in the axial direction, is also provided in the lower
5 portion of the generator.

Coolers 72 for cooling the coolant which has been sucked from the outside of the generator are provided in the ventilating passages 63b, 63d and 63f. The coolers 72a to 72c are arranged in a lower portion of the generator in such a
10 manner as to be aligned in a row in the axial direction. It should be noted that the coolers 72a to 72c may be arranged in an upper portion of the generator. The coolers 72a to 72c are right-left symmetrical with respect to the center line 60. A pipe line for supplying cooling water adit-a pipe line for
15 discharging the cooling water are connected to each of the coolers 72a to 72c. The coolers 72a to 72c are identical to each other in terms of cooling capacity.

A plurality of ventilating circuits including the above-described ventilating passages are formed in the
20 generator. A first ventilating circuit 73, a second ventilating circuit 74, and a third ventilating circuit 75 are formed on one side (left side in Fig. 13) of the center line 60, and, similarly, three ventilating circuits are formed on the other side (right side in Fig. 13) of the center line 60.
25 The three ventilating circuits formed on the one side of the center line 60 are right-left symmetrical to the three ventilating circuits formed on the other side of the center

line 60. Further, the flow of coolant and the temperature rise characteristic on the one side of the center line 60 are right-left symmetrical to those on the other side of the center line 60. Therefore, the configuration of the ventilating circuits and the flow of coolant only on the one side of the center line 60 will be described below.

The first ventilating circuit 73 is an open loop shown by a solid arrow in Fig. 13, which extends from the air suction hole 61 to the fan 59 via the ventilating passage 67, and further extends from the fan 59 to the air discharge hole 62 via the air gap 54, ventilating duct 53, ventilating passage 63a, and ventilating passage 71.

The second ventilating circuit 74 is an open loop shown by a dotted arrow in Fig. 13, which extends from the air suction hole 61 to the fan 59 via the ventilating passage 67, further extending from the fan 59 to the cooler 72a via the ventilating passages 65 and 70, and then extends from the cooler 72a to the air discharge hole 62 via the ventilating passage 63b, ventilating duct 53, air gap 54, ventilating duct 53, and ventilating passages 63c and 71.

The third ventilating circuit 75 is an open loop shown by a dotted arrow in Fig. 13, which extends from the air suction hole 61 to the fan 59 via the ventilating passage 67, further extending from the fan 59 to the cooler 72b via the ventilating passages 65 and 70, and then extends from the cooler 72b to the air discharge hole 62 via the ventilating passage 63d, ventilating duct 53, air gap 54, ventilating duct

53, and ventilating passages 63c and 71.

The flow of coolant will be described below. First, atmospheric air, which is sucked from the air suction hole 61 into the generator by rotation of the fan 59, reaches the air suction side of the fan 59 via the ventilating passage 67. The atmospheric air is boosted by the fan 59, and is allowed to flow from the discharge side of the fan 59 to respective ventilating circuits.

In the first ventilating circuit 73, the atmospheric air boosted by the fan 59 flows axially in the air gap 54 to the ventilating duct 53 communicating with the ventilating passage 63a while cooling the inner peripheral side of the stator iron core 51. The atmospheric air which has reached the ventilating duct 53 communicating with the ventilating passage 63a flows in the ventilating duct 53 from the inner peripheral side to the outer peripheral side of the stator iron core 51, that is, to the ventilating passage 63a, while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air which has reached the ventilating passage 18a cools the outer peripheral side of the stator iron core 51 and flows from the ventilating passage 18a to the air discharge hole 62 via the ventilating passage 71.

In the second ventilating circuit 74, the atmospheric air boosted by the fan 59 flows radially in the ventilating passage 65 to the ventilating passage 70, while cooling the end portion of the stator iron core 51 and the coil end portions of the stator coils 52. The atmospheric air which

has reached the ventilating passage 70 flows axially in the ventilating passage 70 to the cooler 72a. The atmospheric air which has reached the cooler 72a is cooled by the cooler 72a and flows in the ventilating passage 63b in the peripheral direction, while cooling the outer peripheral side of the stator iron core 51, and reaches the ventilating duct 53 communicating with the ventilating passage 63b.

The atmospheric air which has reached the ventilating duct 53 communicating with the ventilating passage 63b flows in the ventilating duct 53 from the outer peripheral side to the inner peripheral side of the stator iron core 51, that is, to the air gap 54, while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air which has reached the air gap 54 flows axially in the air gap 54 to the ventilating duct 53 communicating with the ventilating passage 63c, while cooling the inner peripheral side of the stator iron core 51.

The atmospheric air having reached the ventilating duct 53 communicating with the ventilating passage 63c flows in the ventilating duct 53 from the inner peripheral side to the outer peripheral side of the stator iron core 51, that is, to the ventilating passage 63c, while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air which has reached the ventilating passage 63c cools the outer peripheral side of the stator iron core 51 and flows from the ventilating passage 63c to the air discharge hole 62 via the ventilating passage 71.

In the third ventilating circuit 75, the atmospheric air boosted by the fan 59 flows in the ventilating passage 65 to the ventilating passage 70 while cooling the end portion of the stator iron core 51 and the coil end portions of the stator coils 52. The atmospheric air which has reached the ventilating passage 70 flows axially in the ventilating passage 70 to the cooler 72b. The atmospheric air which has reached the cooler 72b is cooled by the cooler 72b and flows in the ventilating passage 63d in the peripheral direction, while cooling the outer peripheral side of the stator iron core 51 and reaches the ventilating duct 53 communicating with the ventilating passage 63d.

The atmospheric air which has reached the ventilating duct 53 communicating with the ventilating passage 63d flows in the ventilating duct 53 from the outer peripheral side to the inner peripheral side of the stator iron core 51, that is, to the air gap 54, while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air which has reached the air gap 54 flows axially in the air gap 54 to the ventilating duct 53 communicating with to the ventilating passage 63c, while cooling the inner peripheral side of the stator iron core 51.

The atmospheric air which has reached the ventilating duct 53 communicating with the ventilating passage 63c flows in the ventilating duct 53 from the inner peripheral side to the outer peripheral side of the stator iron core 51, that is, to the ventilating passage 63c, while cooling the inside of

the stator iron core 51 and the stator coils 52. The atmospheric air which has reached the ventilating passage 63c cools the outer peripheral side of the stator iron core 51 and flows from the ventilating passage 63c to the air discharge hole 62 via the ventilating passage 71.

According to the embodiment configured as described above, the atmospheric air sucked from the outside of the generator and boosted by the fan 59 is introduced to the ventilating passage 63d positioned at the central portion of the stator iron core 51, being cooled by the cooler 72b, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 51, so that it is possible to supply the atmospheric air, which is sufficiently cooled, to the central portion of the stator iron core 51.

Accordingly, the central portion of the stator iron core 51, at which the temperature of the supplied atmospheric air tends to become highest and the amount of the supplied atmospheric air tends to become smallest, can be cooled by the atmospheric air, which is sufficiently cooled by the cooler, and thereby, local heat generation in the air gap 54 can be suppressed. This makes it possible to level the axial temperature rise distribution in the generator and hence to suppress the thermal oscillation stroke of the rotor.

(Eighth Embodiment)

Fig. 14 shows a configuration of a turbine generator according to an eighth embodiment. This embodiment is a variation of the seventh embodiment. The turbine generator in

this embodiment is of an open type like the seventh embodiment. In this embodiment, coolers 72a and 72b are provided at both ends of a ventilating passage 70 in such a manner as to be right-left symmetrical with respect to a center line 60. The remainder of the configuration is the same as that of the seventh embodiment, and therefore, a description thereof is omitted.

Even in this embodiment, the same effect can be obtained by providing the same ventilating circuits and flow of atmospheric air as those in the seventh embodiment, and further, since the number of the coolers is reduced by one, it is possible to simplify the configuration of the generator and hence to reduce the cost of the generator.

The present invention is applicable to a rotating electric machine in which coolers for cooling a coolant such as air or hydrogen gas are provided. In particular, the present invention is applicable to a rotating electric machine using air as a coolant, that is, an air-cooled generator, and provides an increase in the capacity of a generator, for example, of a hydrogen-cooled type.

- 1 -

DESCRIPTION

ROTATING ELECTRIC MACHINE AND COOLING METHOD THEREOF

Technical Field

The present invention relates to a rotating electric machine in which a cooler for cooling a coolant is provided, *as well as to* *of cooling a rotating electric machine* ~~(and) a [cooling] method [thereof].~~

Background ~~[Art]~~ *of the invention*

A rotating electric machine in which a cooler for cooling a coolant is provided has been ^{*described*} ~~[known]~~, for example, ^{*in*} ~~[from]~~ Japanese Patent Laid-open Nos. Hei 7-177705 and Hei 10-146022. The rotating electric machine described in these documents is configured such that a space between a stator frame and a stator iron core is partitioned into a low temperature gas chamber ^{*to*} ~~[in]~~ which a coolant at a low temperature is supplied, and a high temperature gas chamber, in which the heated coolant flows ^{*a*} ~~[and a]~~ plurality of coolers distributed in the axial direction are provided in a foundation pit under the rotating electric machine, ^{*whereby*} ~~[wherein]~~ the coolant cooled by the plurality of coolers and boosted by a ventilating fan is introduced ^{*various*} ~~to~~ heat sources, such as ^{*the*} ~~[an]~~ iron core and ^{*the*} ~~coils~~, via the low temperature gas chamber, and the coolant ^{*which has*} ~~[having]~~ been used for cooling the

- 2 -

heat sources is ^{returned} [introduced], to the coolers via the high temperature gas chamber.

The above-described rotating electric machine, however, has a problem. Since the coolant, ^{which has} [having] passed through one or two or more of the heat sources is ^{then} introduced to a central portion [in the axial direction] of the iron core, the temperature of the coolant is raised before the coolant reaches the central portion [in the axial] [direction] of the iron core. Accordingly, for the above-described rotating electric machine, if a thermal load generated from the heat sources, such as the iron core and coils, becomes large with an increase in ^{the} generation capacity or in ^{the} loss density, the cooling effect of the coolant introduced to the central portion [in the axial direction] of the iron core is significantly degraded. As a result, ⁱⁿ the above-described rotating electric machine ^{, there is} [has] a possibility that local heat generation ^{will occur} [occurs] in a gap between the stator iron core and a rotor iron core, ^{thereby} to increase the thermal oscillation stroke of the rotor due to uneven thermal expansion of the rotor in the axial direction.

To solve the above-described problem, there may be considered a method of increasing the amount of the coolant or optimizing the distribution of the amounts of the coolant components supplied to respective ventilating passages by adjusting the ventilating resistance; however,

- 3 -

according to the former method, the ventilation loss of the coolant caused upon boosting the coolant by the fan becomes larger, to increase the total loss in ^{the} coolant; and, according to the latter method, since the ventilation resistance must be adjusted while the desired electric and mechanical characteristics are satisfied in ^a (the) limited space, it is difficult to optimize the distribution of the coolant components supplied to the respective ventilating passages.

Summary ^{the}
[Disclosure] of Invention

An object of the present invention is to provide a rotating electric machine ^{which is} capable of ^{exhibiting a level} [leveling the] axial temperature rise distribution [in the machine], and a cooling method thereof.

The basic feature of the present invention is to supply a coolant ^{which is} sufficiently cooled, to a central portion [in the axial direction] of an iron core which is most distant from both axial ends of the iron core. To realize ^{this} [the] feature of the present invention, a plurality of ventilating passages, which continuously extend in the peripheral direction, are provided in the axial direction between a stator frame and a stator iron core, and coolers are provided in at least those ^{passages, which communicate with} [communicated to] the central portion [in the axial direction] of the iron core, of the

- 4 -

plurality of ventilating passages formed in the axial direction, wherein the coolant boosted by a booster is cooled by the coolers and is allowed to flow to the central portion [in the axial direction] of the iron core in the direction from the outer peripheral side to the inner peripheral side of the iron core via the ventilating passages [communicated to the central portion in the axial direction of the iron core].

If ^{an even number of} [the] ventilating passages [of even numbers] are provided, two to four of the ventilating passages, which are located on the central side, constitute the ventilating passages ^{which communicate with} [communicated to] the central portion [in the axial direction] of the iron core. If ^{an odd number of} [the] ventilating passages [of odd numbers] are provided, one to three of the ventilating passages, which are located on the central side, constitute the ventilating passages ^{which communicate with} [communicated to] the central portion [in the axial direction] of the iron core. The number of the ventilating passages is dependent on the capacity of the rotating electric machine. For example, for a generator having a generation capacity of 100 MW class, at least three ventilating passages are provided, and for a generator having a generation capacity of 350 MW class or more, ^{seven to ten or more} ventilating passages [of the number of 7 to 10 or more] are provided.

- 5 -

According to the above feature of the present invention, ^{it is possible to level} ~~(there can be obtained an effect of leveling)~~ the axial temperature rise distribution in the machine. In particular, the above feature is effective ⁱⁿ ~~(to)~~ a rotating electric machine in which the axial length is long and air is used as a coolant, for example, an air-cooled generator having a large capacity. Air which is larger in viscosity than hydrogen exhibits a high ventilating resistance ^{when it flows} ~~(upon)~~ ^a ~~(flowing)~~ in ^a ~~(the)~~ generator, to thereby cause ^a ~~(the)~~ temperature rise. The longer the ventilating distance of air, the larger the ventilating resistance ^{will be} ~~a~~. As a result, for a generator ^{which is} ~~(being)~~ longer in axial length and larger in capacity, the temperature rise of ^{the} ~~a~~ air becomes significantly larger, and the amount of the air supplied to the central portion ~~(in the axial direction)~~ of an iron core becomes smaller.

Accordingly, a small amount of air whose temperature is raised is supplied to the central portion ~~(in the axial direction)~~ of the iron core which is most distant from both the axial ends of the iron core, with a result that there occurs a difference in temperature between each of the axial ends of the iron core and the central portion ~~(in the axial direction)~~ of the iron core. According to the present invention ^{it is possible to supply} ~~(capable of supplying)~~ a coolant ^{which is} ~~sufficiently~~ cooled to the central portion ~~(in the axial direction)~~ of the

- 6 -

iron core, however, it is, ^{also} possible to suppress the temperature rise of the central portion [in the axial] [direction] of the iron core (at) ^{to} an allowable value or less, and, hence, to level the axial temperature rise distribution in the machine.

The leveling of the axial temperature rise distribution in the machine means that the temperature rise of the central portion [in the axial direction] of the iron core is suppressed ^{to} [at] an allowable value or less, to reduce the difference in temperature between each of the axial ends of the iron core and the central portion [in the axial] [direction] of the iron core. Accordingly, there is [any] ^{no} variation in the axial temperature rise distribution in the machine.

Brief Description of Drawings

Fig. 1 is a perspective view, with parts partially cutaway, showing the external appearance and inner configuration of a turbine generator according to a first embodiment of the present invention;

Fig. 2 is a plan view, ^{as} seen in the direction shown by an arrow II of Fig. 1, showing the external configuration of the turbine generator;

Fig. 3 is a plan view, ^{as} seen in the direction shown by an arrow III of Fig. 2, showing the external

- 7 -

configuration of the turbine generator;

Fig. 4 is a sectional view taken on line IV-IV of Fig. 1, showing the inner structure of a portion, positioned under a rotating shaft, of the turbine generator;

Fig. 5 is a perspective view showing the external configuration of a turbine generator according to a second embodiment of the present invention;

Fig. 6 is a sectional view taken on line VI-VI of Fig. 5, showing the inner structure of a portion, positioned over a rotating shaft, of the turbine generator;

Fig. 7 is a sectional view showing the inner structure of a portion, positioned over a rotating shaft, of a turbine generator according to a third embodiment;

Fig. 8 is a sectional view showing the inner structure of a portion, positioned over a rotating shaft, of a turbine generator according to a fourth embodiment of the present invention;

Fig. 9 is a sectional view showing the inner structure of a portion, positioned under a rotating shaft, of a turbine generator according to a fifth embodiment of the present invention;

Fig. 10 is a front view showing the external configuration of a turbine generator according to a sixth embodiment of the present invention;

- 8 -

Fig. 11 is a side view,^{as} seen in the direction shown by an arrow XI of Fig. 10, showing the external configuration of the turbine generator;

Fig. 12 is a sectional top view taken on line XII-XII of Fig. 11, showing the inner configuration of the turbine generator;

Fig. 13 is a sectional view showing the inner configuration of a portion, positioned under a rotating shaft, of a turbine generator according to a seventh embodiment of the present invention; and

Fig. 14 is a sectional view showing the inner configuration of a portion, positioned under a rotating shaft, of a turbine generator according to an eighth embodiment of the present invention.

Best Mode for Carrying Out the Invention

Hereinafter,^{various} embodiments of the present invention will be described with reference to the drawings.

(First Embodiment)

Figs. 1 to 4 show ^{the} (a) configuration of a turbine generator according to a first embodiment of the present invention. The turbine generator in this embodiment is of an enclosed type (or a full-closed type) in which the inside of the generator is cooled with a coolant enclosed in the generator. In these figures, reference numeral 1

- 9 -

designates a stator frame. A cylindrical stator iron core 2 is provided inside the stator frame 1. A plurality of slots 3, which continuously extend in the axial direction, are formed in an inner peripheral portion of the stator iron core 2 in such a manner as to extend in the peripheral direction. Stator coils 4 are enclosed in the slots 3. A plurality of ventilating ducts 5, which continuously extend in the radial direction, are formed in the stator iron core 2 in such a manner as to be spaced from each other at equal intervals in the axial direction.

A rotor iron core 7 is provided on the inner peripheral side of the stator iron core 2, ^{and is disposed} with an air gap 6 [put] between the rotor iron core 7 and the stator iron core 2. A plurality of slots (not shown), which continuously extend in the axial direction, are formed in an outer peripheral portion of the rotor iron core 7 in such a manner as to extend in the peripheral direction. Rotor coils (not shown) are enclosed in the slots of the rotor iron core 7. Cylindrical retaining rings 8 for pressing both ends of the rotor coils are provided at both ends of the rotor iron core 7. A rotating shaft 9 is provided integrally with the rotor iron core 7 in such a manner as to extend in the axial direction along the central axis of the rotor iron core 7.

- 10 -

Annular end brackets 10 functioning as block members are provided at both axial ends of the stator frame 1. A bearing apparatus 11 for rotatably supporting the rotating shaft 9 is provided on the inner peripheral side of each end bracket 10. A current collector 12 for supplying [a] power to the rotor coils during rotation is provided at one end (outside the bearing apparatus 11) of the rotating shaft 9. The current collector 12 is configured to electrically connect the stator side to the rotor side by bringing carbon brushes into press-contact with a current-collecting ring provided at the one end (outside the bearing apparatus 11) of the rotating shaft 9. A connecting portion connected to a turbine ^{), serving} as a ^{driving} [rotating] source ^{for rotating} [of] the generator, is formed at the other end (outside the bearing apparatus 11) of the rotating shaft 9.

Fans 13 for boosting a coolant enclosed in the generator and circulating it in the generator are provided at both ends (inside the bearing apparatuses 11) of the rotating shaft 9. While the fans 13 are used as [the] boosters for boosting ^{the} [a] coolant in this embodiment, other types of boosters may be used. The fans 13 provided at both [the] ends (outside the bearing apparatuses 11) of the rotating shaft 9 are right-left symmetrical with respect to a center line 14. The center line 14 is a bisector which crosses the rotating shaft 9 at right angles at such a

- 11 -

position as to equally divide ^{the} [a] distance between the end brackets 10 into [two] right-left symmetric parts.

Terminals 15 for three-phases ^{of voltage} are provided on the upper surface of the stator frame 1 in such a manner as to project upwardly therefrom. The terminals 15 are used for taking [a] generated power out of the stator coils 4, which are electrically connected to the terminals 15. Hoisting accessories 16 are provided on the front surface of the stator frame 1 at two positions and on the back surface thereof at two positions. For example, when installed in a foundation pit 17, the generator main body is hoisted by a crane via wires fastened to the hoisting accessories 16.

Ventilating passages 18a to 18g, which continuously extend in the peripheral direction, are provided between the stator frame 1 and the stator iron core 2 in parallel to each other in the axial direction. The ventilating passages 18a to 18g are formed by a plurality of annular partition plates 19 for partitioning ^{the} [a] space between the stator frame 1 and the stator iron core 2 in the axial direction, the inner surface of the stator frame 1, and the outer peripheral surface of the stator iron core 2, and [are] ^{they communicate with} ^{in the stator iron core 2} communicated to the ventilating ducts 5. The ventilating passages 18a to 18g are right-left symmetrical with respect to the center line 14.

- 12 -

Ventilating ducts 22a to 22c, extending in the axial direction, are provided on the back surface of the stator frame 1 in parallel ^{with} [to] each other in ^a [the] direction perpendicular to the axial direction. The ventilating ducts 22a and ^{22c} [20c] form ventilating passages 20 continuously extending in the axial direction. The ventilating passages 20 ^{communicate with} [are communicated to] the ventilating passages 18b, 18d, and 18f. The ventilating duct 22b forms a ventilating passage 21 continuously extending in the axial direction. The ventilating passage 21 ^{communicates with} [is communicated to] the ventilating passages 18a, 18c, 18e, and 18g.

Ventilating passages 23 to 26, which continuously extend in the radial direction, are provided between the stator iron core 2 and the end brackets 10. The ventilating passages 23 to 26 are formed by partitioning a space between the stator iron core 2 and the end bracket 10 ^{using} [by] annular partitioning ^{plates} [planes] 27 facing [to] the outer peripheral side of the fan 13. The ventilating passages 23 and 24, each of which ^{provides communication between} [communicates] the discharge side of the fan 13 ^{and} [to] the ventilating passage 20, are right-left symmetrical with respect to the center line 14. The ventilating passages 25 and 26, each of which ^{provides communication between} [communicates] the suction side of the fan 13 ^{and} [to] the ventilating passage 21, are right-left symmetrical with respect to the center line 14.

- 13 -

Each of the ventilating passages 18a to 18g is provided with a cooler [28] for cooling a coolant enclosed in the generator. The coolers 28a to 28g are arranged under the generator in such a manner as to be aligned in a row in the axial direction. It should be noted that the coolers 28a to 28g, ^{also} may be arranged on the upper portion of the generator. The coolers 28a to 28g are ^{disposed so as to be} right-left symmetrical with respect to the center line 14. A pipe line 29 for supplying cooling water and a ^{pipe} [pile] line 30 for discharging cooling water are connected to each of the coolers 28a to 28g. The coolers 28a to 28g are identical to each other in cooling capacity, but are different from each other in external size depending on the size of the ventilating passage 18 on which the cooler is provided. In this embodiment, since the axial width of each of the ventilating passages 18b and 18f is smaller than that of each of the remaining ventilating passages, the axial width of each of the coolers 28b and 28f is made smaller than that of each of the remaining coolers.

A plurality of ventilating circuits configured by the above-described ventilating passages, etc. are formed in the generator. A first ventilating circuit 29, a second ventilating circuit 30, and a third ventilating circuit 31 are formed on one side (left side in Fig. 4) ^{relative to} [from] the center line 14, and similarly three ventilating circuits

- 14 -

are formed on the other side (right side in Fig. 4) ^{relative to} [from] the center line 14. The three ventilating circuits formed on the one side from the center line 14 are right-left ^{relative} symmetrical to the three ventilating circuits formed on the other side from the center line 14. Further, the flow of a coolant and the temperature rise characteristic on the one side from the center line 14 are right-left ^{relative} symmetrical to those on the other side from the center line 14. Therefore, the configuration of the ventilating circuits and the flow of a coolant on ^{only} [the] one side ^{of} [from] the center line 14 will be described below.

The first ventilating circuit 29 is a closed loop designated by a solid arrow in Fig. 4, which extends from the discharge side of the fan 13 to the ventilating duct 5 via the air gap 6, further ^{extends} [extending] from the ventilating duct 5 to the cooler 28a via the ventilating passage 18a, ^{then} and extends from the cooler 28a to the suction side of the fan 13 via the ventilating passages 21 and 25. In the first ventilating circuit 29, heat sources giving heat to the ventilating passages 18a, air gap 6 and ventilating duct 5 are connected in series to the cooler 28a. The heat source giving heat to the air gap 6 and the ventilating passage 18a is the stator iron core 2 generating iron loss, and the heat sources giving heat to the ventilating duct 5 are the stator iron core 2 generating iron loss and the

- 15 -

stator coils 4 generating copper loss.

The second ventilating circuit 30 is a closed loop designated by a dotted arrow in Fig. 4, which extends from the discharge side of the fan 13 to the cooler 28b via the ventilating passage 23, further ^{extends} (extending) from the cooler 28b to the cooler 28c via the ventilating passage 18b, ventilating duct 5, air gap 6, ventilating duct 5, and ventilating passage 18c, and ^{then} extends from the cooler 28c to the suction side of the fan 13 via the ventilating passages 21 and 25. In the second ventilating circuit 30, heat sources and the coolers are alternately arranged in series, and, more specifically, the heat sources giving heat to the ventilating passage 23, the cooler 28b, the heat sources giving heat to the ventilating passages 18b and 18c, 'air' gap 6 and ventilating duct 5, and the cooler 28c are arranged in this order. The heat source giving heat to the air gap 6 and ventilating passages 18b and 18c is the stator iron core 2 generating iron loss, and the heat sources giving heat to the ventilating duct 5 and the ventilating passage 23 are the stator iron core 2 generating iron loss and the stator coils 4 generating copper loss.

The third ventilating circuit 31 is a closed loop designated by a dotted arrow in Fig. 4, which extends from the discharge side of the fan 13 to the cooler 28d via the

The flow of the coolant will be described below. The coolant enclosed in the generator, which is boosted by rotation of the rotating shaft 9, flows from the discharge side of the fan 13 to each ventilating circuit. In the ventilating circuit 29, the coolant boosted by the fan 13 flows axially in the air gap 6 to the ventilating duct 5 *communicating with* the ventilating passage 18a. The coolant

- 17 -

^{which has} [having] reached the ventilating duct 5 ^{communicating with} [communicated to] the ventilating duct 18a flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18a while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant ^{which has} [having] reached the ventilating passage 18a cools the outer peripheral side of the stator iron core 2 and flows in the ventilating passage 18a to the cooler 28a. The coolant ^{which has} [having] reached the cooler 28a is cooled by the cooler 28a and flows from the cooler 28a to the suction side of the fan 13 via the ventilating passages 21 and 25.

In the second ventilating circuit 30, the coolant boosted by the fan 13 flows radially in the ventilating passage 23 to the ventilating passage 20 while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant ^{which has} [having] reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28b. The coolant ^{which has} [having] reached the cooler 28b is cooled by the cooler 28b and flows in the ventilating passage 18b in the peripheral direction while cooling the outer peripheral portion of the stator iron core 2 and reaches the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18b. The coolant ^{which has} [having] reached the ventilating duct 5 ^{communicating with} [communicated to] the ventilating

In the third ventilating circuit 31, the coolant boosted by the fan 13 flows radially in the ventilating passage 23 to the ventilating passage 20 while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant ^{which has} ~~having~~ reached

- 19 -

the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28d. The coolant ^{which has} [having] reached the cooler 28d is cooled by the cooler 28d[,] and flows in the ventilating passage 18d in the peripheral direction while cooling the outer peripheral side of the stator iron core 2 and reaches the ventilating duct 5 ^{communicating with} [communicated to], the ventilating passage 18d. The coolant ^{which has} [having] reached the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18d flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4.

The coolant ^{which has} [having] reached the air gap 6 flows axially in the air gap to the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18c while cooling the inner peripheral side of the stator iron core 2. The coolant ^{which has} [having] reached the ventilating duct 5 ^{communicating with} [communicated] ^{to} the ventilating passage 18c flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18c while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant ^{which has} [having] reached the ventilating passage 18c cools the outer peripheral side of the stator iron core 2[,] and flows in the ventilating passage 18c to the cooler 28c. The coolant

- 20 -

^{which has}
[having] reached the cooler 28c is cooled by the cooler 28c, and flows from the cooler 28c to the suction side of the fan 13 via the ventilating passages 21 and 25.

According to ^{the} [this] embodiment configured as described above, the coolant boosted by the fan 13 is introduced to the ventilating passage 18d positioned at the central portion [in the axial direction] of the stator iron core 2, being cooled by the cooler 28d, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2, so that the coolant sufficiently cooled by the cooler can be supplied to the central portion [in the axial direction] of the stator iron core 2.

Accordingly, the central portion [in the axial] [direction] of the stator iron core 2 at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest can be cooled by the coolant ^{which is} sufficiently cooled by the cooler, and thereby local heat generation in the air gap 6 can be suppressed. This makes it possible to level the axial temperature rise distribution in the generator and hence to suppress the thermal oscillation stroke of the rotor.

(Second Embodiment)

Figs. 5 and 6 show a configuration of a turbine generator according to a second embodiment. The turbine

Ventilating passages 18a to 18d, which continuously extend in the peripheral direction, are provided between a stator frame 1 and a stator iron core 2 in parallel ^{with} (to) each other in the axial direction. The ventilating passages 18b and 18c are ^{in communication with} (communicated to) a ventilating passage 20; and the ventilating passages 18a and 18d are ^{in communication with} (communicated to) a ventilating passage 21. Coolers 28a and 28d are provided in the ventilating passage 21 in such a manner as to be right-left symmetrical with respect to a center line 14, and coolers 28b and 28c are provided in the ventilating passage 20 in such a manner as to be right-left symmetrical with respect to the center line 14. The coolers 28a to 28d are aligned in a row in the axial direction.

The coolers 28b and 28c are smaller in size, that is, *smaller* cooling capacity than the coolers 28a and 28d. One reason for this is that the coolers 28b and 28c are used for

- 22 -

cooling part of a coolant ^{which has} [having] been cooled by the coolers 28a and 28d, and therefore, it is sufficient for the coolers 28b and 28c to be smaller in cooling capacity than the coolers 28a and 28d. This is advantageous in terms of cooling efficiency. Another reason is that, since the ventilating passage 20 in which the coolers 28b and 28c are provided is smaller than the ventilating passage 21 in which the coolers 28a and 28d are provided, the sizes of the coolers 28b and 28c must be made smaller than those of the coolers 28a and 28d. It should be noted that the coolers 28a to 28d may be arranged in the lower portion of the generator.

The other ^{features} [configuration] of this embodiment ^{are} [is] the same as ^{also} [that] of the first embodiment, and therefore, ^a [the] [overlapped] description thereof is omitted. In addition, since the ventilating passages and coolers are respectively right-left symmetrical with respect to the center line 14, and also the flow of a coolant and the temperature rise characteristic are respectively right-left symmetrical with respect to the center line 14, the configuration ^{only} on one side ^{of} [from] the center line 14 will be described below.

The flow of a coolant will be described [below]. When a fan 13 is rotated along with rotation of a rotating shaft 9, a coolant enclosed in the generator is boosted [] and is allowed to flow in respective ventilating passages. The

- 23 -

coolant discharged on the discharge side of the fan 13 is branched into ^{one} [a] component on a ventilating passage 23 side and ^{another} [the other] component on an air gap 6 side. The coolant component branched on the air gap 6 side flows in an air gap 6 to a ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18a while cooling the inner peripheral side of the stator iron core 2.

The coolant component ^{which has} [having] reached the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18a flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18a while cooling the inside of the stator iron core 2 and stator coils 4. The coolant component ^{which has} [having] reached the ventilating passage 18a cools the outer peripheral side of the stator iron core 2 [.] and flows from the ventilating passage 18a to the cooler 28a via the ventilating passage 21. The coolant component ^{which has} [having] reached the cooler 28a is cooled by the cooler 28a [.] and flows from the cooler 28a to the suction side of the fan 13 via the ventilating passage 25.

The coolant component branched on the ventilating passage 23 side flows radially in a ventilating passage 23 to the ventilating passage 20 while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant component ^{which has} [having] reached the

- 24 -

ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28b. The coolant component ^{which has} [having] reached the cooler 28b is cooled by the cooler 28b, and flows from the cooler 28b to the ventilating passage 18b. The coolant component ^{which has} [having] reached the ventilating passage 18b cools the outer peripheral side of the stator iron core 2, and flows in the ventilating passage 18b to the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18b.

The coolant component ^{which has} [having] reached the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18b flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component ^{which has} [having] reached the air gap 6 flows axially in the air gap 6 to the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18a while cooling the inner peripheral side of the stator iron core 2. The coolant component ^{which has} [having] reached the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18a flows in the ventilating ducts 5 together with the above-described coolant component which has been branched from the discharge side of the fan 13 onto the air gap 6 side.

- 25 -

According to this embodiment, part of the coolant cooled by the cooler 28a (or 28d) and boosted by the fan 13 is branched; and the coolant component thus branched is cooled by the cooler 28b (or 28c), being introduced to the ventilating passage 18b (or 18c) positioned at the central portion [in the axial direction] of the stator iron core 2, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2 [and].
Accordingly, it is possible to supply the coolant, which is sufficiently cooled by the cooler, to the central portion in the axial direction of the stator iron core 2.

As a result, according to this embodiment, the central portion [in the axial direction] of the stator iron core 2 at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest can be cooled by the coolant, which is sufficiently cooled by the cooler, so that it is possible to suppress local heat generation in the air gap 6, and hence to level the axial temperature rise distribution in the generator.

(Third Embodiment)

Fig. 7 shows a configuration of a turbine generator according to a third embodiment. This embodiment is a variation of the second embodiment, characterized in that the axial length of the turbine generator in this

- 27 -

The flow of a coolant will be described [below]. When a fan 13 is rotated along with rotation of a rotating shaft 9, a coolant enclosed in the generator is boosted[,] and is allowed to flow in respective ventilating passages. The coolant discharged on the discharge side of the fan 13 is branched ^{into one} [on a] component on a ventilating passage 23 side and ^{another} [the other] component on an air gap 6 side. The coolant component branched on the air gap 6 side flows in an air gap 6 to ventilating ducts 5 ^{communicating with} [communicated to] the ventilating passages 18a and 18b while cooling the inner peripheral side of the stator iron core 2.

The coolant component ^{which has} [having] reached the ventilating ducts 5 ^{communicating with} [communicated to] the ventilating passages 18a and 18b flows in the ventilating ducts 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passages 18a and 18b, while cooling the inside of the stator iron core 2 and stator coils 4. The coolant component ^{which has} [having] reached the ventilating passages 18a and 18b cools the outer peripheral side of the stator iron core 2[,] and flows from the ventilating passages 18a and 18b to the cooler 28a via the ventilating passage 21. The coolant component ^{which has} [having] reached the cooler 28a is cooled by the cooler 28a[,] and flows from the cooler 28a to the suction side of the fan 13 via a ventilating passage 25.

- 28 -

The coolant component branched on the ventilating passage 23 side flows radially in a ventilating passage 23 to the ventilating passage 20, while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant component ^{which has} (having) reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28b. The coolant component ^{which has} (having) reached the cooler 28b is cooled by the cooler 28b[,] and flows from the cooler 28b to the ventilating passage 18c. The coolant component ^{which has} (having) reached the ventilating passage 18c cools the outer peripheral side of the stator iron core 2[,] and flows in the ventilating passage 18c to the ventilating duct 5 ^{communicating with} (communicated to) the ventilating passage 18c.

The coolant component ^{which has} (having) reached the ventilating duct 5 ^{communicating with} (communicated to) the ventilating passage 18c flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6, while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component ^{which has} (having) reached the air gap 6 flows axially in the air gap 6 to the ventilating ducts 5 ^{communicating with} (communicated to) the ventilating passages 18a and 18b, while cooling the inner peripheral side of the stator iron core 2. The coolant component ^{which has} (having) reached the ventilating ducts 5 ^{communicating with} (communicated to) the

- 29 -

ventilating passages 18a and 18b flows in the ventilating ducts 5 together with the above-described coolant component ^{which has} ~~(having)~~ been branched from the discharge side of the fan 13 onto the air gap 6 side.

According to this embodiment, part of the coolant cooled by the cooler 28a (or 28c) and boosted by the fan 13 is branched; and, the coolant component thus branched is cooled by the cooler 28c, being introduced to the ventilating passage 18c positioned at the central portion ~~(in the axial direction)~~ of the stator iron core 2, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2. Accordingly, it is possible to supply the coolant, ^{which is} sufficiently cooled by the cooler, to the central portion ~~(in the axial direction)~~ of the stator iron core 2.

As a result, according to this embodiment, the central portion ~~(in the axial direction)~~ of the stator iron core 2, at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest, can be cooled by the ^{which is} coolant, sufficiently cooled by the cooler, so that it is possible to suppress local heat generation in the air gap 6, and hence to level the axial temperature rise distribution in the generator.

(Fourth Embodiment)

Fig. 8 shows a configuration of a turbine generator according to a fourth embodiment. This embodiment is a combination [example] of the second and third embodiments, characterized in that the axial length of the turbine generator in this embodiment is (further) longer than that of the turbine generator in the third embodiment. Ventilating passages 18a to 18g, which continuously extend in the peripheral direction, are provided between a stator frame 1 and a stator iron core 2 in parallel to each other in the axial direction. The ventilating passages 18a, 18c, 18e and 18g are ^{in communication with} (communicated to) a ventilating passage 21, and the ventilating passage 18d is ^{in communication with} (communicated to) a ventilating passage 20. A ventilating passage 31 for ^{connecting} (communicating) a ventilating passage 23 to the ventilating passage 18b and a ventilating passage 32 for ^{connecting} (communicating) a ventilating passage 24 to the ventilating passage 18f are provided between the stator frame 1 and the stator iron core 2 in such a manner as to be right-left symmetrical with respect to a center line 14.

Coolers 28a and 28e are provided in the ventilating passage 21 in such a manner as to be right-left symmetrical with respect to the center line 14. A cooler 28c is provided in the ventilating passage 20 at a portion communicating with the ventilating passage 18d. The cooler

- 31 -

28c is smaller in size or ^{cooling} [cooling] capacity than each of the coolers 28a and 28e. Coolers 28b and 28d are provided in the ventilating passage 31 in such a manner as to be right-left symmetrical with respect to the center line 14. The coolers 28b and 28d are each smaller [than] in size or cooling capacity than each of the coolers 28a and 28e.

The other ^{features} [configuration] of this embodiment ^{are} [is] the same as ^{that} [that] of each of the second and third embodiments, and, therefore, ^a [the overlapped] description thereof is omitted. In addition, since the ventilating passages and coolers are respectively right-left symmetrical with respect to the center line 14, and also the flow of a coolant and the temperature rise characteristic are respectively right-left symmetrical with respect to the center line 14, the configuration on ^{only} one side [from] ^{of} the center line 14 will be described below.

The flow of a coolant will be described [below]. When a fan 13 is rotated along with rotation of a rotating shaft 9, a coolant enclosed in the generator is boosted [] and is allowed to flow in respective ventilating passages. The coolant discharged on the discharge side of the fan 13 is branched into ^{one} [a] component on a ventilating passage 23 side and ^{another} [the other] component on an air gap 6 side. The coolant component branched on the air gap 6 side flows in an air gap 6 to ventilating ducts 5 ^{communicating with} [communicated to] the

- 32 -

ventilating passages 18a and 18c while cooling the inner peripheral side of the stator iron core 2.

The coolant component ^{which has} [having] reached the ventilating ducts 5 ^{communicating with} [communicated to] the ventilating passages 18a and 18c flows in the ventilating ducts 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passages 18a and 18c, while cooling the inside of the stator iron core 2 and stator coils 4. The coolant component ^{which has} [having] reached the ventilating passages 18a and 18c cools the outer peripheral side of the stator iron core 2[,] and flows from the ventilating passages 18a and 18c to the cooler 28a via the ventilating passage 21. The coolant component [having] ^{which has} reached the cooler 28a is cooled by the cooler 28a[,] and flows from the cooler 28a to the suction side of the fan 13 via a ventilating passage 25.

The coolant component branched onto the ventilating passage 23 side flows radially in the ventilating passage 23 to the ventilating passages 20 and 31, while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant component ^{which has} [having] reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28c. The coolant component ^{which has} [having] reached the cooler 28c is cooled by the cooler 28c[,] and flows from the cooler 28c to the

- 33 -

ventilating passage 18d. The coolant component ^{which has} [having] reached the ventilating passage 18d cools the outer peripheral side of the stator iron core 2[,] and flows in the ventilating passage 18d to the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18d.

The coolant component ^{which has} [having] reached the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18d flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6, while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component ^{which has} [having] reached the air gap 6 flows axially in the air gap 6 to the ventilating ducts 5 ^{communicating with} [communicated to] the ventilating passages 18a and 18c while cooling the inner peripheral side of the stator iron core 2. The coolant component ^{which has} [having] reached the ventilating ducts 5 ^{communicating with} [communicated to] the ventilating passages 18a and 18c flows in the ventilating ducts 5 together with the above-described coolant component ^{which has} [having] been branched from the discharge side of the fan 13 onto the air gap 6 side.

The coolant component ^{which has} [having] reached the ventilating passage 31 flows axially in the ventilating passage 31 to the cooler 28b. The coolant component ^{which has} [having] reached the cooler 28b is cooled by the cooler 28b[,] and flows from the cooler 28b to the ventilating passage 18b. The coolant

- 34 -

component ^{which has} [having] reached the ventilating passage 18b cools the outer peripheral side of the stator ^{iron} [ion] core 2, and flows in the ventilating passage 18b to the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18b.

The coolant component ^{which has} [having] reached the ventilating duct 5 ^{communicating with} [communicated to] the ventilating passage 18b flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6, while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component ^{which has} [having] reached the air gap 6 flows axially in the air gap 6 to the ventilating ducts 5 ^{communicating with} [communicated to] the ventilating passages 18a and 18c, while cooling the inner peripheral side of the stator iron core 2. The coolant component ^{which has} [having] reached the ventilating ducts 5 ^{communicating with} [communicated to] the ventilating passages 18a and 18c flows in the ventilating ducts 5 together with the above-described coolant component ^{which has} [having] been branched from the discharge side of the fan 13 onto the air gap 6 side.

According to this embodiment, part of the coolant cooled by the cooler 28a (or 28e) and boosted by the fan 13 is branched; and, the coolant component thus branched is cooled by the cooler 28c, being introduced to the ventilating passage 18d positioned at the central portion [in the axial direction] of the stator iron core 2, and is

- 35 -

allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2. Accordingly, it is possible to supply the coolant^{which is} sufficiently cooled by the cooler, to the central portion [in the axial direction] of the stator iron core 2.

As a result, according to this embodiment, the central portion [in the axial direction] of the stator iron core 2, at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest, can be cooled by the coolant^{which is} sufficiently cooled by the cooler, so that it is possible to suppress local heat generation in the air gap 6, and hence to level the axial temperature rise distribution in the generator.

(Fifth Embodiment)

Fig. 9 shows a configuration of a turbine generator according to a fifth embodiment. This embodiment is an ^{improvement over} (example improved from) the first embodiment, which is effective ⁱⁿ (to) the case where the axial length of a stator iron core 2 becomes longer. In this embodiment, the axial interval between ^{two} adjacent [two of the] ventilating ducts 5 provided in the stator iron core 2 is set at a large value in a first ventilating circuit 29(,) and is set at a small value in each of second and third ventilating circuits 30 and 31, which ^{are} (is) larger in ventilating distance and thermal

- 36 -

load than the first ventilating circuit 29. The ^{remainder of the} [other] configuration is the same as that of the first embodiment, and therefore, ^a [the overlapped] description thereof is omitted.

According to this embodiment, since the axial interval between ^{two} adjacent [two of the] ventilating ducts 5 differs among the ventilating circuits 29, 30 and 31, it is possible to ^{reduce} [make smaller] the amount of [a] coolant flowing in the first ventilating circuit 29, which is close to ^{the} [a] fan 13, and thereby ^{shorten the} [shorter in] ventilating distance and ^{increase} [make larger] the amount of [the] coolant flowing in each of the second and third ventilating circuits 30 and 31, which ^{are more} [is] distant from a fan 13 and thereby longer in ventilating distance, and hence to improve the effect of cooling the central portion [in the axial direction] of the stator iron core 2 and its neighborhood.

Further, in this embodiment, since the axial interval between ^{two} (the) adjacent [two of the] ventilating ducts 5 differs among the ventilating circuits, it is possible to increase the cooling area of the central portion [in the] [axial direction] of the stator iron core 2 and its neighborhood by ^{reducing} [making small] the exposed area of the stator iron core 2 and stator coils 4 in the first ventilating circuit 29, which ^{has a} [is] small [in] thermal load, and ^{by increasing} [making large], the exposed area of the stator iron core 2 and the stator

- 37 -

coils 4 in each of the second and third ventilating circuits 20 and 31, which ^{have a} [is] large [in] ventilating distance and thermal load, and hence to further improve the effect of cooling the central portion [in the axial direction] of the stator iron core 2 and its neighborhood.

It should be noted that this embodiment has been described as [the example improved from] ^{an improvement over} the first embodiment; however, the configuration of this embodiment ^{as well} may be applied to the other embodiments.

(Sixth Embodiment)

Figs. 10 to 12 show a configuration of a turbine generator according to a sixth embodiment. This embodiment is a variation of the first embodiment, in which the coolers 28 and the ventilating passages 20 and 21 provided in the lower portion of the generator in the first embodiment are provided in both a front portion (front surface side) and a rear portion (back surface side) of the generator. The coolers placed in the vertical direction are aligned in a row in the axial direction on the front and back surfaces of the generator in such a manner as to project therefrom.

A cooler 28a provided in a ventilating passage 18a, a cooler 28c provided in a ventilating passage 18c, a cooler 28e provided in a ventilating passage 18e, and a cooler 28g provided in a ventilating passage 18g are

- 38 -

arranged on the front portion of the generator in such a manner as to be right-left symmetrical with respect to a center line 14. A ventilating passage 21 ^{communicating with} ~~(communicated to)~~, the ventilating passages 18a, 18c, 18e, and 18g is provided in the front portion of the generator.

A cooler 28b provided in a ventilating passage 18b, a cooler 28d provided in a ventilating passage 18d, and a cooler 28f provided in a ventilating passage 18f are arranged on the rear portion of the generator in such a manner as to be right-left symmetrical with respect to the center line 14. A ventilating passage 20 ^{communicating with} ~~(communicated to)~~, the ventilating passages 18b, 18d, and 18e is provided in the front portion of the generator. The ~~[other]~~ ^{remainder of the} configuration is the same as that of the first embodiment, and therefore, ~~(overlapped)~~ ^a description thereof is omitted.

According to this embodiment, the coolers 28a, 28c, 28e, and 28g are arranged on one side (front portion of the generator) of a space between a stator frame 1 and a stator iron core 2 ^{which are} ~~opposed~~ to each other with respect to a rotating shaft 9, and the coolers 28b, 28d, and 28f are arranged on the other side (rear portion of the generator) of the space. Accordingly, in the first, second, and third ventilating circuits 29, 30 and 31, a region in which a coolant flows from the inner peripheral side to the outer peripheral side of the stator iron core 2 and then passes

- 39 -

through the coolers 28 can be formed in the front portion of the generator, and a region in which the coolant passes through the coolers 28 and then flows from the outer peripheral side to the inner peripheral side of the stator iron core 2 can be formed in the rear portion of the generator. As a result, it is possible to eliminate the intersection of the ventilating passages in which the coolant flows, and hence to reduce the ventilating resistance of the coolant. This makes it possible to increase the amount of the coolant (sufficiently cooled) to be supplied to the central portion (of the axial direction) of the stator iron core 2 and its neighborhood, and hence to further improve the effect of cooling the central portion (in the axial direction) of the stator iron core 2.

In this embodiment, description has been made by way of the example in which the coolers are arranged in both the front and rear portions of the generator; however, the same effect can be obtained even by adopting an example in which the coolers are arranged in both the upper and lower portions of the generator.

(Seventh Embodiment)

Fig. 13 shows a configuration of a turbine generator according to a seventh embodiment. The turbine generator in this embodiment is of an open-type in which the inside of the generator is cooled by atmospheric air sucked in the

- 40 -

generator. In the figure, reference numeral 50 designates a stator frame. A cylindrical stator iron core 51 is provided inside the stator frame 50. A plurality of slots, which continuously extend in the axial direction, are formed in an inner peripheral portion of the stator iron core 51 in such a manner as to extend in the peripheral direction. Stator coils 52 are enclosed in the slots. A plurality of ventilating ducts 53, which continuously extend in the radial direction, are formed in the stator iron core 51 in such a manner as to be spaced from each other at equal intervals in the axial direction.

A rotor iron core 55 is provided on the inner peripheral side of the stator iron core 51 with an air gap 54 ^{disposed} [put] between the rotor iron core 55 and the stator iron core 51. A plurality of slots, which continuously extend in the axial direction, are formed in an outer peripheral portion of the rotor iron core 55 in such a manner as to extend in the peripheral direction, and rotor coils are enclosed in the slots. Cylindrical retaining rings 56 for pressing both ends of the rotor coils are provided at both ends of the rotor iron core 55. A rotating shaft 57 is provided integrally with the rotor iron core 55 in such a manner as to extend in the axial direction along the central axis of the rotor iron core 55.

- 41 -

Annular end brackets 58 functioning as block members are provided at both axial ends of the stator frame 50. A bearing apparatus for rotatably supporting the rotating shaft 57 is provided on the inner peripheral side of each end bracket 58. A current collector for supplying [a] power to the rotor coils during rotation is provided at one end (outside the bearing apparatus) of the rotating shaft 57. A connecting portion connected to a turbine ^{sewing} as a (rotating) ^{driving} source of the generator is formed at the other end (outside the bearing apparatus) of the rotating shaft 57.

Fans 59 for boosting a coolant sucked in the generator and circulating it in the generator are provided at both ends (inside the bearing apparatuses) of the rotating shaft 57. While the fans 59 are used as the boosters for boosting ^{the} (a) coolant in this embodiment, other types of boosters may be used. The fans 59 provided at both (the) ends (outside the bearing apparatuses) of the rotating shaft 57 are right-left symmetrical with respect to a center line 60. The center line 60 is a bisector which crosses the rotating shaft 57 at right angles at such a position as to equally divide ^{the} (a) distance between the end brackets 58 into two right-left symmetric parts.

An air suction hole 61 for sucking atmospheric air in the generator is provided on the inner peripheral side of each end bracket 58 in such a manner as to face [to] the

- 42 -

fan 59. An air discharge hole 62 for discharging the atmospheric air ^{which has} [having] been sucked in the generator to the outside of the generator is provided on the outer peripheral side of each end bracket 58.

Ventilating passages 63a to 63g, which continuously extend in the peripheral direction, are provided between the stator frame 50 and the stator iron core 51 in parallel ^{with} (to) each other in the axial direction. The ventilating passages 63a to 63g are formed by a plurality of annular partition plates 64 for partitioning a space between the stator frame 50 and the stator iron core 51 in the axial direction, the inner surface of the stator frame 50, and the outer peripheral surface of the stator iron core 51, and are ^{in communication with} [communicated to] the ventilating ducts 53. The ventilating passages 63a to 63g are right-left symmetrical with respect to the center line 60.

Ventilating passages 65 and 66, which continuously extend in the radial direction, are provided between the stator iron core 51 and the end bracket 58. The ventilating passages 65 and 66 are right-left symmetrical with respect to the center line 60. Ventilating passages 67 and 68, which ^{provide communication between} [communicate] the air suction holes 61 (to) ^{and} the fans 59 and continuously extend in the axial direction, are provided between the end brackets 58 and the fans 59. The ventilating passages 67 and 68 are formed by

- 43 -

partitioning spaces between the stator iron core 51 and the end brackets 58 by means of cylindrical partitioning plates 69, and are right-left symmetrical with respect to the center line 60.

A ventilating passage 70, which ^{connects} (communicates) the ventilating passages 65 and 66 to the ventilating passages 63b, 63d and 63f and continuously extends in the axial direction, is provided in the lower portion of the generator. A ventilating passage 71, which ^{connects} (communicates) the air discharge holes 62 to the ventilating passages 63a, 63c, 63e and 63g and continuously extends in the axial direction, is also provided in the lower portion of the generator.

Coolers 72 for cooling the coolant ^{which has} (having) been sucked from the outside of the generator are provided in the ventilating passages 63b, 63d and 63f. The coolers 72a to 72c are arranged in a lower portion of the generator in such a manner as to be aligned in a row in the axial direction. It should be noted that the coolers 72a to 72c may be arranged in an upper portion of the generator. The coolers 72a to 72c are right-left symmetrical with respect to the center line 60. A pipe line for supplying cooling water and a pipe line for discharging the cooling water are connected to each of the coolers 72a to 72c. The coolers 72a to 72c are identical to each other in terms of cooling

- 44 -

capacity.

A plurality of ventilating circuits including the above-described ventilating passages are formed in the generator. A first ventilating circuit 73, a second ventilating circuit 74, and a third ventilating circuit 75 are formed on one side (left side in Fig. 13) ^{of} (from) the center line 60, and, similarly, three ventilating circuits are formed on the other side (right side in Fig. 13) ^{of} (from) the center line 60. The three ventilating circuits formed on the one side ^{of} (from) the center line 60 are right-left symmetrical to the three ventilating circuits formed on the other side ^{of} (from) the center line 60. Further, the flow of (a) coolant and the temperature rise characteristic on the one side ^{of} (from) the center line 60 are right-left symmetrical to those on the other side ^{of} (from) the center line 60. Therefore, the configuration of the ventilating circuits and the flow of (a) coolant ^{only} on the one side ^{of} (from) the center line 60 will be described below.

The first ventilating circuit 73 is an open loop shown by a solid arrow in Fig. 13, which extends from the air suction hole 61 to the fan 59 via the ventilating passage 67, and further extends from the fan 59 to the air discharge hole 62 via the air gap 54, ventilating duct 53, ventilating passage 63a, and ventilating passage 71.

- 45 -

The second ventilating circuit 74 is an open loop shown by a dotted arrow in Fig. 13, which extends from the air suction hole 61 to the fan 59 via the ventilating passage 67, further extending from the fan 59 to the cooler 72a via the ventilating passages 65 and 70, and ^{then} extends from the cooler 72a to the air discharge hole 62 via the ventilating passage 63b, ventilating duct 53, air gap 54, ventilating duct 53, and ventilating passages 63c and 71.

The third ventilating circuit 75 is an open loop shown by a dotted arrow in Fig. 13, which extends from the air suction hole 61 to the fan 59 via the ventilating passage 67, further extending from the fan 59 to the cooler 72b via the ventilating passages 65 and 70, and ^{then} extends from the cooler 72b to the air discharge hole 62 via 'the' ventilating passage 63d, ventilating duct 53, air gap 54, ventilating duct 53, and ventilating passages 63c and 71.

The flow of (a) coolant will be described below. First, atmospheric air, which is sucked from the air suction hole 61 into the generator by rotation of the fan 59, reaches the air suction side of the fan 59 via the ventilating passage 67. The atmospheric air is boosted by the fan 59, and is allowed to flow from the discharge side of the fan 59 to respective ventilating circuits.

In the first ventilating circuit 73, the atmospheric air boosted by the fan 59 flows axially in the air gap 54

- 46 -

to the ventilating duct 53 ^{communicating with} [communicated to] the ventilating passage 63a while cooling the inner peripheral side of the stator iron core 51. The atmospheric air ^{which has} [having] reached the ventilating duct 53 ^{communicating with} [communicated to] the ventilating passage 63a flows in the ventilating duct 53 from the inner peripheral side to the outer peripheral side of the stator iron core 51, that is, to the ventilating passage 63a, while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air ^{which has} [having] reached the ventilating passage 18a cools the outer peripheral side of the stator iron core 51 [] and flows from the ventilating passage 18a to the air discharge hole 62 via the ventilating passage 71.

In the second ventilating circuit 74, the atmospheric air boosted by the fan 59 flows radially in the ventilating passage 65 to the ventilating passage 70, while cooling the end portion of the stator iron core 51 and the coil end portions of the stator coils 52. The atmospheric air ^{which has} [having] reached the ventilating passage 70 flows axially in the ventilating passage 70 to the cooler 72a. The atmospheric air ^{which has} [having] reached the cooler 72a is cooled by the cooler 72a [] and flows in the ventilating passage 63b in the peripheral direction, while cooling the outer peripheral side of the stator iron core 51, and reaches the ventilating duct 53 ^{communicating with} [communicated to] the ventilating passage 63b.

- 47 -

The atmospheric air, ^{which has} ~~(having)~~ reached ~~(to)~~ the ventilating duct 53, ^{communicating with} ~~(communicated to)~~ the ventilating passage 63b flows in the ventilating duct 53 from the outer peripheral side to the inner peripheral side of the stator iron core 51, that is, to the air gap 54, while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air, ^{which has} ~~(having)~~ reached the air gap 54 flows axially in the air gap 54 to the ventilating duct 53 ^{communicating with} ~~(communicated to)~~ the ventilating passage 63c, while cooling the inner peripheral side of the stator iron core 51.

The atmospheric air having reached the ventilating duct 53 ^{communicating with} ~~(communicated to)~~ the ventilating passage 63c flows in the ventilating duct 53 from the inner peripheral side to the outer peripheral side of the stator iron core '51,' that is, to the ventilating passage 63c, while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air ^{which has} ~~(having)~~ reached the ventilating passage 63c cools the outer peripheral side of the stator iron core 51, and flows from the ventilating passage 63c to the air discharge hole 62 via the ventilating passage 71.

In the third ventilating circuit 75, the atmospheric air boosted by the fan 59 flows in the ventilating passage 65 to the ventilating passage 70 while cooling the end portion of the stator iron core 51 and the coil end portions of the stator coils 52. The atmospheric air

- 48 -

which has
[having] reached the ventilating passage 70 flows axially in the ventilating passage 70 to the cooler 72b. The atmospheric air *which has* [having] reached the cooler 72b is cooled by the cooler 72b and flows in the ventilating passage 63d in the peripheral direction, while cooling the outer peripheral side of the stator iron core 51 and reaches the ventilating duct 53 *communicating with* [communicated to] the ventilating passage 63d.

The atmospheric air *which has* [having] reached the ventilating duct 53 *communicating with* [communicated to] the ventilating passage 63d flows in the ventilating duct 53 from the outer peripheral side to the inner peripheral side of the stator iron core 51, that is, to the air gap 54, while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air *which has* [having] reached the air gap 54 flows axially in the air gap 54 to the ventilating duct 53 *communicating with* [communicated to] the ventilating passage 63c, while cooling the inner peripheral side of the stator iron core 51.

The atmospheric air *which has* [having] reached the ventilating duct 53 *communicating with* [communicated to] the ventilating passage 63c flows in the ventilating duct 53 from the inner peripheral side to the outer peripheral side of the stator iron core 51, that is, to the ventilating passage 63c, while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air *which has* [having] reached the ventilating passage 63c cools the outer peripheral side of the stator iron core

51,) and flows from the ventilating passage 63c to the air discharge hole 62 via the ventilating passage 71.

According to (this) embodiment configured as described above, the atmospheric air sucked from the outside of the generator and boosted by the fan 59 is introduced to the ventilating passage 63d positioned at the central portion (in the axial direction) of the stator iron core 51, being cooled by the cooler 72b, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 51, so that it is possible to supply the atmospheric air, ^{which is} sufficiently cooled, to the central portion (in the axial direction) of the stator iron core 51.

Accordingly, the central portion (in the axial direction) of the stator iron core 51, at which the temperature of the supplied atmospheric air tends to become highest and the amount of the supplied atmospheric air tends to become smallest, can be cooled by the atmospheric air, which is sufficiently cooled by the cooler, and thereby, local heat generation in the air gap 54 can be suppressed. This makes it possible to level the axial temperature rise distribution in the generator and hence to suppress the thermal oscillation stroke of the rotor.

(Eighth Embodiment)

Fig. 14 shows a configuration of a turbine generator according to an eighth embodiment. This embodiment is a

- 50 -

variation of the seventh embodiment. The turbine generator in this embodiment is of an open type like the seventh embodiment. In this embodiment, coolers 72a and 72b are provided at both ends of a ventilating passage 70 in such a manner as to be right-left symmetrical with respect to a center line 60. The ^{remainder of the} [other] configuration is the same as that of the seventh embodiment, and therefore, [the] ^a [overlapped] description thereof is omitted.

Even in this embodiment, the same effect can be obtained by providing the same ventilating circuits and flow of atmospheric air as those in the seventh embodiment, and further, since the number of the coolers is reduced by one, it is possible to simplify the configuration of the generator and hence to reduce the cost of the generator.

[Industrial Applicability]

The present invention is ^{applicable} [effective] to a rotating electric machine in which coolers for cooling a coolant such as air or hydrogen gas are provided. In particular, the present invention is ^{applicable} [effective] to a rotating electric machine using air as a coolant, that is, an air-cooled generator, and ^{provides for an} [is allowed to] increase ⁱⁿ the capacity of a generator, for example, of a hydrogen-cooled type.

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- 1 -

DESCRIPTION

ROTATING ELECTRIC MACHINE AND COOLING METHOD THEREOF

Technical Field

The present invention relates to a rotating electric machine in which a cooler for cooling a coolant is provided, and a cooling method thereof.

Background Art

A rotating electric machine in which a cooler for cooling a coolant is provided has been known, for example, from Japanese Patent Laid-open Nos. Hei 7-177705 and Hei 10-146022. The rotating electric machine described in these documents is configured such that a space between a stator frame and a stator iron core is partitioned into a low temperature gas chamber in which a coolant at a low temperature is supplied and a high temperature gas chamber in which the heated coolant flows, and a plurality of coolers distributed in the axial direction are provided in a foundation pit under the rotating electric machine, wherein the coolant cooled by the plurality of coolers and boosted by a ventilating fan is introduced to heat sources such as an iron core and coils via the low temperature gas chamber and the coolant having been used for cooling the

- 2 -

heat sources is introduced to the coolers via the high temperature gas chamber.

The above-described rotating electric machine, however, has a problem. Since the coolant having passed through one or two or more of the heat sources is introduced to a central portion in the axial direction of the iron core, the temperature of the coolant is raised before the coolant reaches the central portion in the axial direction of the iron core. Accordingly, for the above-described rotating electric machine, if a thermal load generated from the heat sources such as the iron core and coils becomes large with an increase in generation capacity or in loss density, the cooling effect of the coolant introduced to the central portion in the axial direction of the iron core is significantly degraded. As a result, the above-described rotating electric machine has a possibility that local heat generation occurs in a gap between the stator iron core and a rotor iron core, to increase the thermal oscillation stroke of the rotor due to uneven thermal expansion of the rotor in the axial direction.

To solve the above-described problem, there may be considered a method of increasing the amount of the coolant or optimizing the distribution of the amounts of the coolant components supplied to respective ventilating passages by adjusting the ventilating resistance; however,

- 3 -

according to the former method, the ventilation loss of the coolant caused upon boosting the coolant by the fan becomes larger, to increase the total loss in coolant; and according to the latter method, since the ventilation resistance must be adjusted while the desired electric and mechanical characteristics are satisfied in the limited space, it is difficult to optimize the distribution of the coolant components supplied to the respective ventilating passages.

Disclosure of Invention

An object of the present invention is to provide a rotating electric machine capable of leveling the axial temperature rise distribution in the machine, and a cooling method thereof.

The basic feature of the present invention is to supply a coolant sufficiently cooled to a central portion in the axial direction of an iron core which is most distant from both axial ends of the iron core. To realize the feature of the present invention, a plurality of ventilating passages, which continuously extend in the peripheral direction, are provided in the axial direction between a stator frame and a stator iron core, and coolers are provided in at least those, communicated to the central portion in the axial direction of the iron core, of the

- 4 -

plurality of ventilating passages formed in the axial direction, wherein the coolant boosted by a booster is cooled by the coolers and is allowed to flow to the central portion in the axial direction of the iron core in the direction from the outer peripheral side to the inner peripheral side of the iron core via the ventilating passages communicated to the central portion in the axial direction of the iron core.

If the ventilating passages of even numbers are provided, two to four of the ventilating passages, which are located on the central side, constitute the ventilating passages communicated to the central portion in the axial direction of the iron core. If the ventilating passages of odd numbers are provided, one to three of the ventilating passages, which are located on the central side, constitute the ventilating passages communicated to the central portion in the axial direction of the iron core. The number of the ventilating passages is dependent on the capacity of the rotating electric machine. For example, for a generator having a generation capacity of 100 MW class, at least three ventilating passages are provided, and for a generator having a generation capacity of 350 MW class or more, ventilating passages of the number of 7 to 10 or more are provided.

- 5 -

According to the above feature of the present invention, there can be obtained an effect of leveling the axial temperature rise distribution in the machine. In particular, the above feature is effective to a rotating electric machine in which the axial length is long and air is used as a coolant, for example, an air-cooled generator having a large capacity. Air which is larger in viscosity than hydrogen exhibits a high ventilating resistance upon flowing in the generator, to thereby cause the temperature rise. The longer the ventilating distance of air, the larger the ventilating resistance. As a result, for a generator being longer in axial length and larger in capacity, the temperature rise of air becomes significantly larger, and the amount of the air supplied to the central portion in the axial direction of an iron core becomes smaller.

Accordingly, a small amount of air whose temperature is raised is supplied to the central portion in the axial direction of the iron core which is most distant from both the axial ends of the iron core, with a result that there occurs a difference in temperature between each of the axial ends of the iron core and the central portion in the axial direction of the iron core. According to the present invention capable of supplying a coolant sufficiently cooled to the central portion in the axial direction of the

- 6 -

iron core, however, it is possible to suppress the temperature rise of the central portion in the axial direction of the iron core at an allowable value or less, and hence to level the axial temperature rise distribution in the machine.

The leveling of the axial temperature rise distribution in the machine means that the temperature rise of the central portion in the axial direction of the iron core is suppressed at an allowable value or less, to reduce the difference in temperature between each of the axial ends of the iron core and the central portion in the axial direction of the iron core. Accordingly, there is any variation in the axial temperature rise distribution in the machine.

Brief Description of Drawings

Fig. 1 is a perspective view, with parts partially cutaway, showing the external appearance and inner configuration of a turbine generator according to a first embodiment of the present invention;

Fig. 2 is a plan view, seen in the direction shown by an arrow II of Fig. 1, showing the external configuration of the turbine generator;

Fig. 3 is a plan view, seen in the direction shown by an arrow III of Fig. 2, showing the external

- 7 -

configuration of the turbine generator;

Fig. 4 is a sectional view taken on line IV-IV of Fig. 1, showing the inner structure of a portion, positioned under a rotating shaft, of the turbine generator;

Fig. 5 is a perspective view showing the external configuration of a turbine generator according to a second embodiment of the present invention;

Fig. 6 is a sectional view taken on line VI-VI of Fig. 5, showing the inner structure of a portion, positioned over a rotating shaft, of the turbine generator;

Fig. 7 is a sectional view showing the inner structure of a portion, positioned over a rotating shaft, of a turbine generator according to a third embodiment;

Fig. 8 is a sectional view showing the inner structure of a portion, positioned over a rotating shaft, of a turbine generator according to a fourth embodiment of the present invention;

Fig. 9 is a sectional view showing the inner structure of a portion, positioned under a rotating shaft, of a turbine generator according to a fifth embodiment of the present invention;

Fig. 10 is a front view showing the external configuration of a turbine generator according to a sixth embodiment of the present invention;

- 8 -

Fig. 11 is a side view, seen in the direction shown by an arrow XI of Fig. 10, showing the external configuration of the turbine generator;

Fig. 12 is a sectional top view taken on line XII-XII of Fig. 11, showing the inner configuration of the turbine generator;

Fig. 13 is a sectional view showing the inner configuration of a portion, positioned under a rotating shaft, of a turbine generator according to a seventh embodiment of the present invention; and

Fig. 14 is a sectional view showing the inner configuration of a portion, positioned under a rotating shaft, of a turbine generator according to an eighth embodiment of the present invention.

Best Mode for Carrying Out the Invention

Hereinafter, embodiments of the present invention will be described with reference to the drawings.

(First Embodiment)

Figs. 1 to 4 show a configuration of a turbine generator according to a first embodiment of the present invention. The turbine generator in this embodiment is of an enclosed type (or a full-closed type) in which the inside of the generator is cooled with a coolant enclosed in the generator. In these figures, reference numeral 1

- 9 -

designates a stator frame. A cylindrical stator iron core 2 is provided inside the stator frame 1. A plurality of slots 3, which continuously extend in the axial direction, are formed in an inner peripheral portion of the stator iron core 2 in such a manner as to extend in the peripheral direction. Stator coils 4 are enclosed in the slots 3. A plurality of ventilating ducts 5, which continuously extend in the radial direction, are formed in the stator iron core 2 in such a manner as to be spaced from each other at equal intervals in the axial direction.

A rotor iron core 7 is provided on the inner peripheral side of the stator iron core 2 with an air gap 6 put between the rotor iron core 7 and the stator iron core 2. A plurality of slots (not shown), which continuously extend in the axial direction, are formed in an outer peripheral portion of the rotor iron core 7 in such a manner as to extend in the peripheral direction. Rotor coils (not shown) are enclosed in the slots of the rotor iron core 7. Cylindrical retaining rings 8 for pressing both ends of the rotor coils are provided at both ends of the rotor iron core 7. A rotating shaft 9 is provided integrally with the rotor iron core 7 in such a manner as to extend in the axial direction along the central axis of the rotor iron core 7.

- 10 -

Annular end brackets 10 functioning as block members are provided at both axial ends of the stator frame 1. A bearing apparatus 11 for rotatably supporting the rotating shaft 9 is provided on the inner peripheral side of each end bracket 10. A current collector 12 for supplying a power to the rotor coils during rotation is provided at one end (outside the bearing apparatus 11) of the rotating shaft 9. The current collector 12 is configured to electrically connect the stator side to the rotor side by bringing carbon brushes into press-contact with a current-collecting ring provided at the one end (outside the bearing apparatus 11) of the rotating shaft 9. A connecting portion connected to a turbine as a rotating source of the generator is formed at the other end (outside the bearing apparatus 11) of the rotating shaft 9.

Fans 13 for boosting a coolant enclosed in the generator and circulating it in the generator are provided at both ends (inside the bearing apparatuses 11) of the rotating shaft 9. While the fans 13 are used as the boosters for boosting a coolant in this embodiment, other types of boosters may be used. The fans 13 provided at both the ends (outside the bearing apparatuses 11) of the rotating shaft 9 are right-left symmetrical with respect to a center line 14. The center line 14 is a bisector which crosses the rotating shaft 9 at right angles at such a

- 11 -

position as to equally divide a distance between the end brackets 10 into two right-left symmetric parts.

Terminals 15 for three-phases are provided on the upper surface of the stator frame 1 in such a manner as to project upwardly therefrom. The terminals 15 are used for taking a generated power out of the stator coils 4 electrically connected to the terminals 15. Hoisting accessories 16 are provided on the front surface of the stator frame 1 at two positions and on the back surface thereof at two positions. For example, when installed in a foundation pit 17, the generator main body is hoisted by a crane via wires fastened to the hoisting accessories 16.

Ventilating passages 18a to 18g, which continuously extend in the peripheral direction, are provided between the stator frame 1 and the stator iron core 2 in parallel to each other in the axial direction. The ventilating passages 18a to 18g are formed by a plurality of annular partition plates 19 for partitioning a space between the stator frame 1 and the stator iron core 2 in the axial direction, the inner surface of the stator frame 1, and the outer peripheral surface of the stator iron core 2, and are communicated to the ventilating ducts 5. The ventilating passages 18a to 18g are right-left symmetrical with respect to the center line 14.

- 12 -

Ventilating ducts 22a to 22c, extending in the axial direction, are provided on the back surface of the stator frame 1 in parallel to each other in the direction perpendicular to the axial direction. The ventilating ducts 22a and 20c form ventilating passages 20 continuously extending in the axial direction. The ventilating passages 20 are communicated to the ventilating passages 18b, 18d, and 18f. The ventilating duct 22b forms a ventilating passage 21 continuously extending in the axial direction. The ventilating passage 21 is communicated to the ventilating passages 18a, 18c, 18e, and 18g.

Ventilating passages 23 to 26, which continuously extend in the radial direction, are provided between the stator iron core 2 and the end brackets 10. The ventilating passages 23 to 26 are formed by partitioning a space between the stator iron core 2 and the end bracket 10 by annular partitioning planes 27 facing to the outer peripheral side of the fan 13. The ventilating passages 23 and 24, each of which communicates the discharge side of the fan 13 to the ventilating passage 20, are right-left symmetrical with respect to the center line 14. The ventilating passages 25 and 26, each of which communicates the suction side of the fan 13 to the ventilating passage 21, are right-left symmetrical with respect to the center line 14.

- 13 -

Each of the ventilating passages 18a to 18g is provided with a cooler 28 for cooling a coolant enclosed in the generator. The coolers 28a to 28g are arranged under the generator in such a manner as to be aligned in a row in the axial direction. It should be noted that the coolers 28a to 28g may be arranged on the upper portion of the generator. The coolers 28a to 28g are right-left symmetrical with respect to the center line 14. A pipe line 29 for supplying cooling water and a pile line 30 for discharging cooling water are connected to each of the coolers 28a to 28g. The coolers 28a to 28g are identical to each other in cooling capacity, but are different from each other in external size depending on the size of the ventilating passage 18 on which the cooler is provided. In this embodiment, since the axial width of each of the ventilating passages 18b and 18f is smaller than that of each of the remaining ventilating passages, the axial width of each of the coolers 28b and 28f is made smaller than that of each of the remaining coolers.

A plurality of ventilating circuits configured by the above-described ventilating passages, etc. are formed in the generator. A first ventilating circuit 29, a second ventilating circuit 30, and a third ventilating circuit 31 are formed on one side (left side in Fig. 4) from the center line 14, and similarly three ventilating circuits

- 14 -

are formed on the other side (right side in Fig. 4) from the center line 14. The three ventilating circuits formed on the one side from the center line 14 are right-left symmetrical to the three ventilating circuits formed on the other side from the center line 14. Further, the flow of a coolant and the temperature rise characteristic on the one side from the center line 14 are right-left symmetrical to those on the other side from the center line 14. Therefore, the configuration of the ventilating circuits and the flow of a coolant on the one side from the center line 14 will be described below.

The first ventilating circuit 29 is a closed loop designated by a solid arrow in Fig. 4, which extends from the discharge side of the fan 13 to the ventilating duct 5 via the air gap 6, further extending from the ventilating duct 5 to the cooler 28a via the ventilating passage 18a, and extends from the cooler 28a to the suction side of the fan 13 via the ventilating passages 21 and 25. In the first ventilating circuit 29, heat sources giving heat to the ventilating passages 18a, air gap 6 and ventilating duct 5 are connected in series to the cooler 28a. The heat source giving heat to the air gap 6 and the ventilating passage 18a is the stator iron core 2 generating iron loss, and the heat sources giving heat to the ventilating duct 5 are the stator iron core 2 generating iron loss and the

- 15 -

stator coils 4 generating copper loss.

The second ventilating circuit 30 is a closed loop designated by a dotted arrow in Fig. 4, which extends from the discharge side of the fan 13 to the cooler 28b via the ventilating passage 23, further extending from the cooler 28b to the cooler 28c via the ventilating passage 18b, ventilating duct 5, air gap 6, ventilating duct 5, and ventilating passage 18c, and extends from the cooler 28c to the suction side of the fan 13 via the ventilating passages 21 and 25. In the second ventilating circuit 30, heat sources and the coolers are alternately arranged in series, and more specifically, the heat sources giving heat to the ventilating passage 23, the cooler 28b, the heat sources giving heat to the ventilating passages 18b and 18c, air gap 6 and ventilating duct 5, and the cooler 28c are arranged in this order. The heat source giving heat to the air gap 6 and ventilating passages 18b and 18c is the stator iron core 2 generating iron loss, and the heat sources giving heat to the ventilating duct 5 and the ventilating passage 23 are the stator iron core 2 generating iron loss and the stator coils 4 generating copper loss.

The third ventilating circuit 31 is a closed loop designated by a dotted arrow in Fig. 4, which extends from the discharge side of the fan 13 to the cooler 28d via the

- 16 -

ventilating passage 23, further extending from the cooler 28d to the cooler 28c via the ventilating passage 18d, ventilating duct 5, air gap 6, ventilating duct 5, and ventilating passage 18c, and extends from the cooler 28c to the suction side of the fan 13 via the ventilating passages 21 and 25. In the second ventilating circuit 30, heat sources and the coolers are alternately arranged in series, and more specifically, the heat sources giving heat to the ventilating passage 23, the cooler 28d, the heat sources giving heat to the ventilating passages 18d and 18c, air gap 6, and ventilating duct 5, and the cooler 28c are arranged in series in this order. The heat source giving heat to the air gap 6 and the ventilating passages 18d and 18c is the stator iron core 2 generating iron loss, and the heat sources giving heat to the ventilating duct 5 and the ventilating passage 23 are the stator iron core 2 generating iron loss and the stator coils 4 generating copper loss.

The flow of the coolant will be described below. The coolant enclosed in the generator, which is boosted by rotation of the rotating shaft 9, flows from the discharge side of the fan 13 to each ventilating circuit. In the ventilating circuit 29, the coolant boosted by the fan 13 flows axially in the air gap 6 to the ventilating duct 5 communicated to the ventilating passage 18a. The coolant

- 17 -

having reached the ventilating duct 5 communicated to the ventilating duct 18a flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18a while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant having reached the ventilating passage 18a cools the outer peripheral side of the stator iron core 2, and flows in the ventilating passage 18a to the cooler 28a. The coolant having reached the cooler 28a is cooled by the cooler 28a, and flows from the cooler 28a to the suction side of the fan 13 via the ventilating passages 21 and 25.

In the second ventilating circuit 30, the coolant boosted by the fan 13 flows radially in the ventilating passage 23 to the ventilating passage 20 while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant having reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28b. The coolant having reached the cooler 28b is cooled by the cooler 28b, and flows in the ventilating passage 18b in the peripheral direction while cooling the outer peripheral portion of the stator iron core 2 and reaches the ventilating duct 5 communicated to the ventilating passage 18b. The coolant having reached the ventilating duct 5 communicated to the ventilating

- 18 -

passage 18b flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4.

The coolant having reached the air gap 6 flows axially in the air gap 6 to the ventilating duct 5 communicated to the ventilating passage 18c while cooling the inner peripheral side of the stator iron core 2. The coolant having reached the ventilating duct 5 communicated to the ventilating passage 18c flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18c while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant having reached the ventilating passage 18c cools the outer peripheral side of the stator iron core 2, and flows in the ventilating passage 18c to the cooler 28c. The coolant having reached the cooler 28c is cooled by the cooler 28c, and flows from the cooler 28c to the suction side of the fan 13 via the ventilating passages 21 and 25.

In the third ventilating circuit 31, the coolant boosted by the fan 13 flows radially in the ventilating passage 23 to the ventilating passage 20 while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant having reached

- 19 -

the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28d. The coolant having reached the cooler 28d is cooled by the cooler 28d, and flows in the ventilating passage 18d in the peripheral direction while cooling the outer peripheral side of the stator iron core 2 and reaches the ventilating duct 5 communicated to the ventilating passage 18d. The coolant having reached the ventilating duct 5 communicated to the ventilating passage 18d flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4.

The coolant having reached the air gap 6 flows axially in the air gap to the ventilating duct 5 communicated to the ventilating passage 18c while cooling the inner peripheral side of the stator iron core 2. The coolant having reached the ventilating duct 5 communicated to the ventilating passage 18c flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18c while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant having reached the ventilating passage 18c cools the outer peripheral side of the stator iron core 2, and flows in the ventilating passage 18c to the cooler 28c. The coolant

- 20 -

having reached the cooler 28c is cooled by the cooler 28c, and flows from the cooler 28c to the suction side of the fan 13 via the ventilating passages 21 and 25.

According to this embodiment configured as described above, the coolant boosted by the fan 13 is introduced to the ventilating passage 18d positioned at the central portion in the axial direction of the stator iron core 2, being cooled by the cooler 28d, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2, so that the coolant sufficiently cooled by the cooler can be supplied to the central portion in the axial direction of the stator iron core 2.

Accordingly, the central portion in the axial direction of the stator iron core 2 at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest can be cooled by the coolant sufficiently cooled by the cooler, and thereby local heat generation in the air gap 6 can be suppressed. This makes it possible to level the axial temperature rise distribution in the generator and hence to suppress the thermal oscillation stroke of the rotor.

(Second Embodiment)

Figs. 5 and 6 show a configuration of a turbine generator according to a second embodiment. The turbine

- 21 -

generator in this embodiment is of an enclosed type (or a full-closed type) like the turbine generator in the first embodiment but is shorter in axial length (or smaller in generation capacity) than the turbine generator in the first embodiment. Further, the turbine generator in this embodiment is configured such that the coolers 28 and the ventilating passages 20 and 21 provided in the lower portion of the generator in the first embodiment are provided in an upper portion of the generator.

Ventilating passages 18a to 18d, which continuously extend in the peripheral direction, are provided between a stator frame 1 and a stator iron core 2 in parallel to each other in the axial direction. The ventilating passages 18b and 18c are communicated to a ventilating passage 20, and the ventilating passages 18a and 18d are communicated to a ventilating passage 21. Coolers 28a and 28d are provided in the ventilating passage 21 in such a manner as to be right-left symmetrical with respect to a center line 14, and coolers 28b and 28c are provided in the ventilating passage 20 in such a manner as to be right-left symmetrical with respect to the center line 14. The coolers 28a to 28d are aligned in a row in the axial direction.

The coolers 28b and 28c are smaller in size, that is, cooling capacity than the coolers 28a and 28d. One reason for this is that the coolers 28b and 28c are used for

- 22 -

cooling part of a coolant having been cooled by the coolers 28a and 28d, and therefore, it is sufficient for the coolers 28b and 28c to be smaller in cooling capacity than the coolers 28a and 28d. This is advantageous in terms of cooling efficiency. Another reason is that since the ventilating passage 20 in which the coolers 28b and 28c are provided is smaller than the ventilating passage 21 in which the coolers 28a and 28d are provided, the sizes of the coolers 28b and 28c must be made smaller than those of the coolers 28a and 28d. It should be noted that the coolers 28a to 28d may be arranged in the lower portion of the generator.

The other configuration of this embodiment is the same as that of the first embodiment, and therefore, the overlapped description thereof is omitted. In addition, since the ventilating passages and coolers are respectively right-left symmetrical with respect to the center line 14, and also the flow of a coolant and the temperature rise characteristic are respectively right-left symmetrical with respect to the center line 14, the configuration on one side from the center line 14 will be described below.

The flow of a coolant will be described below. When a fan 13 is rotated along with rotation of a rotating shaft 9, a coolant enclosed in the generator is boosted, and is allowed to flow in respective ventilating passages. The

- 23 -

coolant discharged on the discharge side of the fan 13 is branched into a component on a ventilating passage 23 side and the other component on an air gap 6 side. The coolant component branched on the air gap 6 side flows in an air gap 6 to a ventilating duct 5 communicated to the ventilating passage 18a while cooling the inner peripheral side of the stator iron core 2.

The coolant component having reached the ventilating duct 5 communicated to the ventilating passage 18a flows in the ventilating duct 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passage 18a while cooling the inside of the stator iron core 2 and stator coils 4. The coolant component having reached the ventilating passage 18a cools the outer peripheral side of the stator iron core 2, and flows from the ventilating passage 18a to the cooler 28a via the ventilating passage 21. The coolant component having reached the cooler 28a is cooled by the cooler 28a, and flows from the cooler 28a to the suction side of the fan 13 via the ventilating passage 25.

The coolant component branched on the ventilating passage 23 side flows radially in a ventilating passage 23 to the ventilating passage 20 while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant component having reached the

- 24 -

ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28b. The coolant component having reached the cooler 28b is cooled by the cooler 28b, and flows from the cooler 28b to the ventilating passage 18b. The coolant component having reached the ventilating passage 18b cools the outer peripheral side of the stator iron core 2, and flows in the ventilating passage 18b to the ventilating duct 5 communicated to the ventilating passage 18b.

The coolant component having reached the ventilating duct 5 communicated to the ventilating passage 18b flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component having reached the air gap 6 flows axially in the air gap 6 to the ventilating duct 5 communicated to the ventilating passage 18a while cooling the inner peripheral side of the stator iron core 2. The coolant component having reached the ventilating duct 5 communicated to the ventilating passage 18a flows in the ventilating ducts 5 together with the above-described coolant component which has been branched from the discharge side of the fan 13 onto the air gap 6 side.

- 25 -

According to this embodiment, part of the coolant cooled by the cooler 28a (or 28d) and boosted by the fan 13 is branched; and the coolant component thus branched is cooled by the cooler 28b (or 28c), being introduced to the ventilating passage 18b (or 18c) positioned at the central portion in the axial direction of the stator iron core 2, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2, and accordingly, it is possible to supply the coolant sufficiently cooled by the cooler to the central portion in the axial direction of the stator iron core 2.

As a result, according to this embodiment, the central portion in the axial direction of the stator iron core 2 at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest can be cooled by the coolant sufficiently cooled by the cooler, so that it is possible to suppress local heat generation in the air gap 6, and hence to level the axial temperature rise distribution in the generator.

(Third Embodiment)

Fig. 7 shows a configuration of a turbine generator according to a third embodiment. This embodiment is a variation of the second embodiment, characterized in that the axial length of the turbine generator in this

- 26 -

embodiment is longer than that of the turbine generator in the second embodiment. Ventilating passages 18a to 18e, which continuously extend in the peripheral direction, are provided between a stator frame 1 and a stator iron core 2 in parallel to each other in the axial direction. The ventilating passages 18a, 18b, 18d and 18e are communicated to a ventilating passage 21, and the ventilating passage 18c is communicated to a ventilating passage 20. Coolers 28a and 28c are provided in the ventilating passage 21 in such a manner as to be right-left symmetrical with respect to a center line 14, and a cooler 28b is provided in the ventilating passage 20 at a communicating portion communicated to the ventilating passage 18c. The cooler 28b is smaller in size or cooling capacity than each of the coolers 28a and 28c.

The other configuration of this embodiment is the same as that of the second embodiment, and therefore, the overlapped description thereof is omitted. In addition, since the ventilating passages and coolers are respectively right-left symmetrical with respect to the center line 14, and also the flow of a coolant and the temperature rise characteristic are respectively right-left symmetrical with respect to the center line 14, the configuration on one side from the center line 14 will be described below.

- 27 -

The flow of a coolant will be described below. When a fan 13 is rotated along with rotation of a rotating shaft 9, a coolant enclosed in the generator is boosted, and is allowed to flow in respective ventilating passages. The coolant discharged on the discharge side of the fan 13 is branched on a component on a ventilating passage 23 side and the other component on an air gap 6 side. The coolant component branched on the air gap 6 side flows in an air gap 6 to ventilating ducts 5 communicated to the ventilating passages 18a and 18b while cooling the inner peripheral side of the stator iron core 2.

The coolant component having reached the ventilating ducts 5 communicated to the ventilating passages 18a and 18b flows in the ventilating ducts 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passages 18a and 18b while cooling the inside of the stator iron core 2 and stator coils 4. The coolant component having reached the ventilating passages 18a and 18b cools the outer peripheral side of the stator iron core 2, and flows from the ventilating passages 18a and 18b to the cooler 28a via the ventilating passage 21. The coolant component having reached the cooler 28a is cooled by the cooler 28a, and flows from the cooler 28a to the suction side of the fan 13 via a ventilating passage 25.

- 28 -

The coolant component branched on the ventilating passage 23 side flows radially in a ventilating passage 23 to the ventilating passage 20 while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant component having reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28b. The coolant component having reached the cooler 28b is cooled by the cooler 28b, and flows from the cooler 28b to the ventilating passage 18c. The coolant component having reached the ventilating passage 18c cools the outer peripheral side of the stator iron core 2, and flows in the ventilating passage 18c to the ventilating duct 5 communicated to the ventilating passage 18c.

The coolant component having reached the ventilating duct 5 communicated to the ventilating passage 18c flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component having reached the air gap 6 flows axially in the air gap 6 to the ventilating ducts 5 communicated to the ventilating passages 18a and 18b while cooling the inner peripheral side of the stator iron core 2. The coolant component having reached the ventilating ducts 5 communicated to the

- 29 -

ventilating passages 18a and 18b flows in the ventilating ducts 5 together with the above-described coolant component having been branched from the discharge side of the fan 13 onto the air gap 6 side.

According to this embodiment, part of the coolant cooled by the cooler 28a (or 28c) and boosted by the fan 13 is branched; and the coolant component thus branched is cooled by the cooler 28c, being introduced to the ventilating passage 18c positioned at the central portion in the axial direction of the stator iron core 2, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2. Accordingly, it is possible to supply the coolant sufficiently cooled by the cooler to the central portion in the axial direction of the stator iron core 2.

As a result, according to this embodiment, the central portion in the axial direction of the stator iron core 2 at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest can be cooled by the coolant sufficiently cooled by the cooler, so that it is possible to suppress local heat generation in the air gap 6, and hence to level the axial temperature rise distribution in the generator.

- 30 -

(Fourth Embodiment)

Fig. 8 shows a configuration of a turbine generator according to a fourth embodiment. This embodiment is a combination example of the second and third embodiments, characterized in that the axial length of the turbine generator in this embodiment is further longer than that of the turbine generator in the third embodiment. Ventilating passages 18a to 18g, which continuously extend in the peripheral direction, are provided between a stator frame 1 and a stator iron core 2 in parallel to each other in the axial direction. The ventilating passages 18a, 18c, 18e and 18g are communicated to a ventilating passage 21, and the ventilating passage 18d is communicated to a ventilating passage 20. A ventilating passage 31 for communicating a ventilating passage 23 to the ventilating passage 18b and a ventilating passage 32 for communicating a ventilating passage 24 to the ventilating passage 18f are provided between the stator frame 1 and the stator iron core 2 in such a manner as to be right-left symmetrical with respect to a center line 14.

Coolers 28a and 28e are provided in the ventilating passage 21 in such a manner as to be right-left symmetrical with respect to the center line 14. A cooler 28c is provided in the ventilating passage 20 at a portion communicated to the ventilating passage 18d. The cooler

- 31 -

28c is smaller in size or cooling capacity than each of the coolers 28a and 28e. Coolers 28b and 28d are provided in the ventilating passage 31 in such a manner as to be right-left symmetrical with respect to the center line 14. The coolers 28b and 28d are each smaller than in size or cooling capacity than each of the coolers 28a and 28e.

The other configuration of this embodiment is the same as that of each of the second and third embodiments, and therefore, the overlapped description thereof is omitted. In addition, since the ventilating passages and coolers are respectively right-left symmetrical with respect to the center line 14, and also the flow of a coolant and the temperature rise characteristic are respectively right-left symmetrical with respect to the center line 14, the configuration on one side from the center line 14 will be described below.

The flow of a coolant will be described below. When a fan 13 is rotated along with rotation of a rotating shaft 9, a coolant enclosed in the generator is boosted, and is allowed to flow in respective ventilating passages. The coolant discharged on the discharge side of the fan 13 is branched into a component on a ventilating passage 23 side and the other component on an air gap 6 side. The coolant component branched on the air gap 6 side flows in an air gap 6 to ventilating ducts 5 communicated to the

- 32 -

ventilating passages 18a and 18c while cooling the inner peripheral side of the stator iron core 2.

The coolant component having reached the ventilating ducts 5 communicated to the ventilating passages 18a and 18c flows in the ventilating ducts 5 from the inner peripheral side to the outer peripheral side of the stator iron core 2, that is, to the ventilating passages 18a and 18c while cooling the inside of the stator iron core 2 and stator coils 4. The coolant component having reached the ventilating passages 18a and 18c cools the outer peripheral side of the stator iron core 2, and flows from the ventilating passages 18a and 18c to the cooler 28a via the ventilating passage 21. The coolant component having reached the cooler 28a is cooled by the cooler 28a, and flows from the cooler 28a to the suction side of the fan 13 via a ventilating passage 25.

The coolant component branched onto the ventilating passage 23 side flows radially in the ventilating passage 23 to the ventilating passages 20 and 31 while cooling the end portion of the stator iron core 2 and the coil end portions of the stator coils 4. The coolant component having reached the ventilating passage 20 flows axially in the ventilating passage 20 to the cooler 28c. The coolant component having reached the cooler 28c is cooled by the cooler 28c, and flows from the cooler 28c to the

- 33 -

ventilating passage 18d. The coolant component having reached the ventilating passage 18d cools the outer peripheral side of the stator iron core 2, and flows in the ventilating passage 18d to the ventilating duct 5 communicated to the ventilating passage 18d.

The coolant component having reached the ventilating duct 5 communicated to the ventilating passage 18d flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component having reached the air gap 6 flows axially in the air gap 6 to the ventilating ducts 5 communicated to the ventilating passages 18a and 18c while cooling the inner peripheral side of the stator iron core 2. The coolant component having reached the ventilating ducts 5 communicated to the ventilating passages 18a and 18c flows in the ventilating ducts 5 together with the above-described coolant component having been branched from the discharge side of the fan 13 onto the air gap 6 side.

The coolant component having reached the ventilating passage 31 flows axially in the ventilating passage 31 to the cooler 28b. The coolant component having reached the cooler 28b is cooled by the cooler 28b, and flows from the cooler 28b to the ventilating passage 18b. The coolant

- 34 -

component having reached the ventilating passage 18b cools the outer peripheral side of the stator iron core 2, and flows in the ventilating passage 18b to the ventilating duct 5 communicated to the ventilating passage 18b.

The coolant component having reached the ventilating duct 5 communicated to the ventilating passage 18b flows in the ventilating duct 5 from the outer peripheral side to the inner peripheral side of the stator iron core 2, that is, to the air gap 6 while cooling the inside of the stator iron core 2 and the stator coils 4. The coolant component having reached the air gap 6 flows axially in the air gap 6 to the ventilating ducts 5 communicated to the ventilating passages 18a and 18c while cooling the inner peripheral side of the stator iron core 2. The coolant component having reached the ventilating ducts 5 communicated to the ventilating passages 18a and 18c flows in the ventilating ducts 5 together with the above-described coolant component having been branched from the discharge side of the fan 13 onto the air gap 6 side.

According to this embodiment, part of the coolant cooled by the cooler 28a (or 28e) and boosted by the fan 13 is branched; and the coolant component thus branched is cooled by the cooler 28c, being introduced to the ventilating passage 18d positioned at the central portion in the axial direction of the stator iron core 2, and is

- 35 -

allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 2. Accordingly, it is possible to supply the coolant sufficiently cooled by the cooler to the central portion in the axial direction of the stator iron core 2.

As a result, according to this embodiment, the central portion in the axial direction of the stator iron core 2 at which the temperature of the supplied coolant tends to become highest and the amount of the supplied coolant tends to become smallest can be cooled by the coolant sufficiently cooled by the cooler, so that it is possible to suppress local heat generation in the air gap 6, and hence to level the axial temperature rise distribution in the generator.

(Fifth Embodiment)

Fig. 9 shows a configuration of a turbine generator according to a fifth embodiment. This embodiment is an example improved from the first embodiment, which is effective to the case where the axial length of a stator iron core 2 becomes longer. In this embodiment, the axial interval between adjacent two of the ventilating ducts 5 provided in the stator iron core 2 is set at a large value in a first ventilating circuit 29, and is set at a small value in each of second and third ventilating circuits 30 and 31, which is larger in ventilating distance and thermal

- 36 -

load than the first ventilating circuit 29. The other configuration is the same as that of the first embodiment, and therefore, the overlapped description thereof is omitted.

According to this embodiment, since the axial interval between adjacent two of the ventilating ducts 5 differs among the ventilating circuits 29, 30 and 31, it is possible to make smaller the amount of a coolant flowing in the first ventilating circuit 29 which is close to a fan 13 and thereby shorter in ventilating distance and make larger the amount of the coolant flowing in each of the second and third ventilating circuits 30 and 31 which is distant from a fan 13 and thereby longer in ventilating distance, and hence to improve the effect of cooling the central portion in the axial direction of the stator iron core 2 and its neighborhood.

Further, in this embodiment, since the axial interval between the adjacent two of the ventilating ducts 5 differs among the ventilating circuits, it is possible to increase the cooling area of the central portion in the axial direction of the stator iron core 2 and its neighborhood by making small the exposed area of the stator iron core 2 and stator coils 4 in the first ventilating circuit 29 which is small in thermal load and making large the exposed area of the stator iron core 2 and the stator

- 37 -

coils 4 in each of the second and third ventilating circuits 20 and 31 which is large in ventilating distance and thermal load, and hence to further improve the effect of cooling the central portion in the axial direction of the stator iron core 2 and its neighborhood.

It should be noted that this embodiment has been described as the example improved from the first embodiment; however, the configuration of this embodiment may be applied to the other embodiments.

(Sixth Embodiment)

Figs. 10 to 12 show a configuration of a turbine generator according to a sixth embodiment. This embodiment is a variation of the first embodiment, in which the coolers 28 and the ventilating passages 20 and 21 provided in the lower portion of the generator in the first embodiment are provided in both a front portion (front surface side) and a rear portion (back surface side) of the generator. The coolers placed in the vertical direction are aligned in a row in the axial direction on the front and back surfaces of the generator in such a manner as to project therefrom.

A cooler 28a provided in a ventilating passage 18a, a cooler 28c provided in a ventilating passage 18c, a cooler 28e provided in a ventilating passage 18e, and a cooler 28g provided in a ventilating passage 18g are

- 38 -

arranged on the front portion of the generator in such a manner as to be right-left symmetrical with respect to a center line 14. A ventilating passage 21 communicated to the ventilating passages 18a, 18c, 18e, and 18g is provided in the front portion of the generator.

A cooler 28b provided in a ventilating passage 18b, a cooler 28d provided in a ventilating passage 18d, and a cooler 28f provided in a ventilating passage 18f are arranged on the rear portion of the generator in such a manner as to be right-left symmetrical with respect to the center line 14. A ventilating passage 20 communicated to the ventilating passages 18b, 18d, and 18e is provided in the front portion of the generator. The other configuration is the same as that of the first embodiment, and therefore, overlapped description thereof is omitted.

According to this embodiment, the coolers 28a, 28c, 28e, and 28g are arranged on one side (front portion of the generator) of a space between a stator frame 1 and a stator iron core 2 opposed to each other with respect to a rotating shaft 9, and the coolers 28b, 28d, and 28f are arranged on the other side (rear portion of the generator) of the space. Accordingly, in the first, second, and third ventilating circuits 29, 30 and 31, a region in which a coolant flows from the inner peripheral side to the outer peripheral side of the stator iron core 2 and then passes

- 39 -

through the coolers 28 can be formed in the front portion of the generator, and a region in which the coolant passes through the coolers 28 and then flows from the outer peripheral side to the inner peripheral side of the stator iron core 2 can be formed in the rear portion of the generator. As a result, it is possible to eliminate the intersection of the ventilating passages in which the coolant flows, and hence to reduce the ventilating resistance of the coolant. This makes it possible to increase the amount of the coolant sufficiently cooled to be supplied to the central portion of the axial direction of the stator iron core 2 and its neighborhood, and hence to further improve the effect of cooling the central portion in the axial direction of the stator iron core 2.

In this embodiment, description has been made by way of the example in which the coolers are arranged in both the front and rear portions of the generator; however, the same effect can be obtained even by adopting an example in which the coolers are arranged in both the upper and lower portions of the generator.

(Seventh Embodiment)

Fig. 13 shows a configuration of a turbine generator according to a seventh embodiment. The turbine generator in this embodiment is of an open-type in which the inside of the generator is cooled by atmospheric air sucked in the

- 40 -

generator. In the figure, reference numeral 50 designates a stator frame. A cylindrical stator iron core 51 is provided inside the stator frame 50. A plurality of slots, which continuously extend in the axial direction, are formed in an inner peripheral portion of the stator iron core 51 in such a manner as to extend in the peripheral direction. Stator coils 52 are enclosed in the slots. A plurality of ventilating ducts 53, which continuously extend in the radial direction, are formed in the stator iron core 51 in such a manner as to be spaced from each other at equal intervals in the axial direction.

A rotor iron core 55 is provided on the inner peripheral side of the stator iron core 51 with an air gap 54 put between the rotor iron core 55 and the stator iron core 51. A plurality of slots, which continuously extend in the axial direction, are formed in an outer peripheral portion of the rotor iron core 55 in such a manner as to extend in the peripheral direction, and rotor coils are enclosed in the slots. Cylindrical retaining rings 56 for pressing both ends of the rotor coils are provided at both ends of the rotor iron core 55. A rotating shaft 57 is provided integrally with the rotor iron core 55 in such a manner as to extend in the axial direction along the central axis of the rotor iron core 55.

- 41 -

Annular end brackets 58 functioning as block members are provided at both axial ends of the stator frame 50. A bearing apparatus for rotatably supporting the rotating shaft 57 is provided on the inner peripheral side of each end bracket 58. A current collector for supplying a power to the rotor coils during rotation is provided at one end (outside the bearing apparatus) of the rotating shaft 57. A connecting portion connected to a turbine as a rotating source of the generator is formed at the other end (outside the bearing apparatus) of the rotating shaft 57.

Fans 59 for boosting a coolant sucked in the generator and circulating it in the generator are provided at both ends (inside the bearing apparatuses) of the rotating shaft 57. While the fans 59 are used as the boosters for boosting a coolant in this embodiment, other types of boosters may be used. The fans 59 provided at both the ends (outside the bearing apparatuses) of the rotating shaft 57 are right-left symmetrical with respect to a center line 60. The center line 60 is a bisector which crosses the rotating shaft 57 at right angles at such a position as to equally divide a distance between the end brackets 58 into two right-left symmetric parts.

An air suction hole 61 for sucking atmospheric air in the generator is provided on the inner peripheral side of each end bracket 58 in such a manner as to face to the

- 42 -

fan 59. An air discharge hole 62 for discharging the atmospheric air having been sucked in the generator to the outside of the generator is provided on the outer peripheral side of each end bracket 58.

Ventilating passages 63a to 63g, which continuously extend in the peripheral direction, are provided between the stator frame 50 and the stator iron core 51 in parallel to each other in the axial direction. The ventilating passages 63a to 63g are formed by a plurality of annular partition plates 64 for partitioning a space between the stator frame 50 and the stator iron core 51 in the axial direction, the inner surface of the stator frame 50, and the outer peripheral surface of the stator iron core 51, and are communicated to the ventilating ducts 53. The ventilating passages 63a to 63g are right-left symmetrical with respect to the center line 60.

Ventilating passages 65 and 66, which continuously extend in the radial direction, are provided between the stator iron core 51 and the end bracket 58. The ventilating passages 65 and 66 are right-left symmetrical with respect to the center line 60. Ventilating passages 67 and 68, which communicate the air suction holes 61 to the fans 59 and continuously extend in the axial direction, are provided between the end brackets 58 and the fans 59. The ventilating passages 67 and 68 are formed by

- 43 -

partitioning spaces between the stator iron core 51 and the end brackets 58 by means of cylindrical partitioning plates 69, and are right-left symmetrical with respect to the center line 60.

A ventilating passage 70, which communicates the ventilating passages 65 and 66 to the ventilating passages 63b, 63d and 63f and continuously extends in the axial direction, is provided in the lower portion of the generator. A ventilating passage 71, which communicates the air discharge holes 62 to the ventilating passages 63a, 63c, 63e and 63g and continuously extends in the axial direction, is also provided in the lower portion of the generator.

Coolers 72 for cooling the coolant having been sucked from the outside of the generator are provided in the ventilating passages 63b, 63d and 63f. The coolers 72a to 72c are arranged in a lower portion of the generator in such a manner as to be aligned in a row in the axial direction. It should be noted that the coolers 72a to 72c may be arranged in an upper portion of the generator. The coolers 72a to 72c are right-left symmetrical with respect to the center line 60. A pipe line for supplying cooling water and a pipe line for discharging the cooling water are connected to each of the coolers 72a to 72c. The coolers 72a to 72c are identical to each other in terms of cooling

- 44 -

capacity.

A plurality of ventilating circuits including the above-described ventilating passages are formed in the generator. A first ventilating circuit 73, a second ventilating circuit 74, and a third ventilating circuit 75 are formed on one side (left side in Fig. 13) from the center line 60, and similarly three ventilating circuits are formed on the other side (right side in Fig. 13) from the center line 60. The three ventilating circuits formed on the one side from the center line 60 are right-left symmetrical to the three ventilating circuits formed on the other side from the center line 60. Further, the flow of a coolant and the temperature rise characteristic on the one side from the center line 60 are right-left symmetrical to those on the other side from the center line 60. Therefore, the configuration of the ventilating circuits and the flow of a coolant on the one side from the center line 60 will be described below.

The first ventilating circuit 73 is an open loop shown by a solid arrow in Fig. 13, which extends from the air suction hole 61 to the fan 59 via the ventilating passage 67, and further extends from the fan 59 to the air discharge hole 62 via the air gap 54, ventilating duct 53, ventilating passage 63a, and ventilating passage 71.

- 45 -

The second ventilating circuit 74 is an open loop shown by a dotted arrow in Fig. 13, which extends from the air suction hole 61 to the fan 59 via the ventilating passage 67, further extending from the fan 59 to the cooler 72a via the ventilating passages 65 and 70, and extends from the cooler 72a to the air discharge hole 62 via the ventilating passage 63b, ventilating duct 53, air gap 54, ventilating duct 53, and ventilating passages 63c and 71.

The third ventilating circuit 75 is an open loop shown by a dotted arrow in Fig. 13, which extends from the air suction hole 61 to the fan 59 via the ventilating passage 67, further extending from the fan 59 to the cooler 72b via the ventilating passages 65 and 70, and extends from the cooler 72b to the air discharge hole 62 via the ventilating passage 63d, ventilating duct 53, air gap 54, ventilating duct 53, and ventilating passages 63c and 71.

The flow of a coolant will be described below. First, atmospheric air, which is sucked from the air suction hole 61 into the generator by rotation of the fan 59, reaches the air suction side of the fan 59 via the ventilating passage 67. The atmospheric air is boosted by the fan 59, and is allowed to flow from the discharge side of the fan 59 to respective ventilating circuits.

In the first ventilating circuit 73, the atmospheric air boosted by the fan 59 flows axially in the air gap 54

- 46 -

to the ventilating duct 53 communicated to the ventilating passage 63a while cooling the inner peripheral side of the stator iron core 51. The atmospheric air having reached the ventilating duct 53 communicated to the ventilating passage 63a flows in the ventilating duct 53 from the inner peripheral side to the outer peripheral side of the stator iron core 51, that is, to the ventilating passage 63a while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air having reached the ventilating passage 18a cools the outer peripheral side of the stator iron core 51, and flows from the ventilating passage 18a to the air discharge hole 62 via the ventilating passage 71.

In the second ventilating circuit 74, the atmospheric air boosted by the fan 59 flows radially in the ventilating passage 65 to the ventilating passage 70 while cooling the end portion of the stator iron core 51 and the coil end portions of the stator coils 52. The atmospheric air having reached the ventilating passage 70 flows axially in the ventilating passage 70 to the cooler 72a. The atmospheric air having reached the cooler 72a is cooled by the cooler 72a, and flows in the ventilating passage 63b in the peripheral direction while cooling the outer peripheral side of the stator iron core 51 and reaches the ventilating duct 53 communicated to the ventilating passage 63b.

- 47 -

The atmospheric air having reached to the ventilating duct 53 communicated to the ventilating passage 63b flows in the ventilating duct 53 from the outer peripheral side to the inner peripheral side of the stator iron core 51, that is, to the air gap 54 while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air having reached the air gap 54 flows axially in the air gap 54 to the ventilating duct 53 communicated to the ventilating passage 63c while cooling the inner peripheral side of the stator iron core 51.

The atmospheric air having reached the ventilating duct 53 communicated to the ventilating passage 63c flows in the ventilating duct 53 from the inner peripheral side to the outer peripheral side of the stator iron core 51, that is, to the ventilating passage 63c while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air having reached the ventilating passage 63c cools the outer peripheral side of the stator iron core 51, and flows from the ventilating passage 63c to the air discharge hole 62 via the ventilating passage 71.

In the third ventilating circuit 75, the atmospheric air boosted by the fan 59 flows in the ventilating passage 65 to the ventilating passage 70 while cooling the end portion of the stator iron core 51 and the coil end portions of the stator coils 52. The atmospheric air

- 48 -

having reached the ventilating passage 70 flows axially in the ventilating passage 70 to the cooler 72b. The atmospheric air having reached the cooler 72b is cooled by the cooler 72b, and flows in the ventilating passage 63d in the peripheral direction while cooling the outer peripheral side of the stator iron core 51 and reaches the ventilating duct 53 communicated to the ventilating passage 63d.

The atmospheric air having reached the ventilating duct 53 communicated to the ventilating passage 63d flows in the ventilating duct 53 from the outer peripheral side to the inner peripheral side of the stator iron core 51, that is, to the air gap 54 while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air having reached the air gap 54 flows axially in the air gap 54 to the ventilating duct 53 communicated to the ventilating passage 63c while cooling the inner peripheral side of the stator iron core 51.

The atmospheric air having reached the ventilating duct 53 communicated to the ventilating passage 63c flows in the ventilating duct 53 from the inner peripheral side to the outer peripheral side of the stator iron core 51, that is, to the ventilating passage 63c while cooling the inside of the stator iron core 51 and the stator coils 52. The atmospheric air having reached the ventilating passage 63c cools the outer peripheral side of the stator iron core

- 49 -

51, and flows from the ventilating passage 63c to the air discharge hole 62 via the ventilating passage 71.

According to this embodiment configured as described above, the atmospheric air sucked from the outside of the generator and boosted by the fan 59 is introduced to the ventilating passage 63d positioned at the central portion in the axial direction of the stator iron core 51, being cooled by the cooler 72b, and is allowed to flow from the outer peripheral side to the inner peripheral side of the stator iron core 51, so that it is possible to supply the atmospheric air sufficiently cooled to the central portion in the axial direction of the stator iron core 51.

Accordingly, the central portion in the axial direction of the stator iron core 51 at which the temperature of the supplied atmospheric air tends to become highest and the amount of the supplied atmospheric air tends to become smallest can be cooled by the atmospheric air sufficiently cooled by the cooler, and thereby local heat generation in the air gap 54 can be suppressed. This makes it possible to level the axial temperature rise distribution in the generator and hence to suppress the thermal oscillation stroke of the rotor.

(Eighth Embodiment)

Fig. 14 shows a configuration of a turbine generator according to an eighth embodiment. This embodiment is a

- 50 -

variation of the seventh embodiment. The turbine generator in this embodiment is of an open type like the seventh embodiment. In this embodiment, coolers 72a and 72b are provided at both ends of a ventilating passage 70 in such a manner as to be right-left symmetrical with respect to a center line 60. The other configuration is the same as that of the seventh embodiment, and therefore, the overlapped description thereof is omitted.

Even in this embodiment, the same effect can be obtained by providing the same ventilating circuits and flow of atmospheric air as those in the seventh embodiment, and further, since the number of the coolers is reduced by one, it is possible to simplify the configuration of the generator and hence to reduce the cost of the generator.

Industrial Applicability

The present invention is effective to a rotating electric machine in which coolers for cooling a coolant such as air or hydrogen gas are provided. In particular, the present invention is effective to a rotating electric machine using air as a coolant, that is, an air-cooled generator, and is allowed to increase the capacity of a generator, for example, of a hydrogen-cooled type.

- 51 -

CLAIMS

1. A rotating electric machine comprising:

a plurality of ventilating passages formed between a stator frame and a stator iron core;

a cooler provided at least in one, communicated to a central portion in the axial direction of said stator iron core, of said plurality of ventilating passages;

a booster for boosting a coolant; and

a ventilating circuit in which the coolant boosted by said booster, being cooled by said cooler, and is allowed to flow to said central portion in the axial direction of said stator iron core in the direction from the outer peripheral side to the inner peripheral side of said stator iron core via said ventilating passage communicated to said central portion in the axial direction of said stator iron core.

2. A rotating electric machine comprising:

a plurality of ventilating passages formed between a stator frame and a stator iron core;

coolers provided in said plurality of said ventilating passages;

a booster for boosting a coolant; and

a ventilating circuit in which part or all of the coolant cooled by one of said coolers and boosted by said booster is further cooled by another of said coolers, and

- 52 -

is allowed to flow to a central portion in the axial direction of said stator iron core in the direction from the outer peripheral side to the inner peripheral side of said stator iron core at least via one, communicated to said central portion in the axial direction of said stator iron core, of said plurality of ventilating passages.

3. A rotating electric machine comprising:

a plurality of ventilating passages formed between a stator frame and a stator iron core;

coolers provided in said plurality of ventilating passages;

a fan for boosting a coolant;

a first ventilating circuit in which the coolant boosted by said fan is introduced from the inner peripheral side of said stator iron core into some of said ventilating passages and is cooled by some of said coolers; and

a second ventilating circuit in which the coolant boosted by said fan is cooled by some of said coolers and is allowed to flow to said stator iron core in the direction from the outer peripheral side to the inner peripheral side of said stator iron core via some of said ventilating passages;

wherein at least one, communicated to a central portion in the axial direction of said stator iron core, of said plurality of ventilating passages constitutes part of

- 53 -

said second ventilating circuit.

4. A rotating electric machine comprising:

a plurality of ventilating passages formed between a stator frame and a stator iron core;

coolers provided in said plurality of ventilating passages;

a fan for boosting the coolant;

a first ventilating circuit in which the coolant boosted by said fan is introduced from the inner peripheral side of said stator iron core to some of said ventilating passages and is cooled by some of said coolers; and

a second ventilating circuit in which the coolant boosted by said fan and branched from said first ventilating circuit is cooled by some of said coolers, and is allowed to flow to said stator iron core in the direction from the outer peripheral side to the inner peripheral side of said stator iron core;

wherein at least one, communicated to a central portion in the axial direction of said stator iron core, of said plurality of ventilating passages constitutes part of said second ventilating circuit.

5. A rotating electric machine in which the inside of said machine is cooled by a coolant enclosed therein, comprising:

- 54 -

a plurality of ventilating passages formed between a stator frame and a stator iron core;

coolers provided in said plurality of ventilating passages;

a fan for boosting a coolant;

a first ventilating circuit in which the coolant boosted by said fan is introduced from the inner peripheral side of said stator iron core into some of said ventilating passages and is cooled by some of said coolers; and

a second ventilating circuit in which the coolant boosted by said fan is cooled by some of said coolers and is allowed to flow to said stator iron core in the direction from the outer peripheral side to the inner peripheral side of said stator iron core via some of said ventilating passages;

wherein at least one, communicated to a central portion in the axial direction of said stator iron core, of said plurality of ventilating passages constitutes part of said second ventilating circuit.

6. A rotating electric machine in which the inside of said machine is cooled by atmospheric air sucked from outside said machine, comprising:

a plurality of ventilating passages formed between a stator frame and a stator iron core;

- 55 -

a fan for boosting a coolant;

a first ventilating circuit in which the atmospheric air boosted by said fan is introduced from the inner peripheral side of said stator iron core into some of said ventilating passages; and

a second ventilating circuit in which the atmospheric air boosted by said fan is allowed to flow to said stator iron core in the direction from the outer peripheral side to the inner peripheral side of said stator iron core via some of said ventilating passages;

wherein a cooler is provided at least in one, which constitutes part of said second ventilating circuit and which is communicated to a central portion in the axial direction of said stator iron core, of said plurality of ventilating passages.

7. A rotating electric machine in which the inside of said machine is cooled by atmospheric air sucked from outside said machine, comprising:

a plurality of ventilating passages formed between a stator frame and a stator iron core;

a fan for boosting a coolant;

a first ventilating circuit in which the atmospheric air boosted by said fan is introduced from the inner peripheral side of said stator iron core into some of said ventilating passages; and

- 56 -

a second ventilating circuit in which the atmospheric air boosted by said fan is allowed to flow to said stator iron core in the direction from the outer peripheral side to the inner peripheral side of said stator iron core via some of said ventilating passages;

wherein a cooler is provided at least on the way of a ventilating passage for communicating an atmospheric air suction hole to one, which constitutes part of said second ventilating circuit and which is communicated to a central portion in the axial direction of said stator iron core, of said plurality of ventilating passages.

8. A rotating electric machine according to any one of claims 1 to 7, wherein said coolers are provided in an upper or lower portion of said rotating electric machine.

9. A rotating electric machine comprising:

a plurality of ventilating passages formed between a stator frame and a stator iron core;

coolers provided in said plurality of ventilating passages;

a fan for boosting a coolant;

a first ventilating circuit in which the coolant boosted by said fan is introduced from the inner peripheral side of said stator iron core into some of said ventilating passages and is cooled by some of said coolers; and

- 57 -

a second ventilating circuit in which the coolant boosted by said fan is cooled by some of said coolers and is allowed to flow to said stator iron core in the direction from the outer peripheral side to the inner peripheral side of said stator iron core via some of said ventilating passages;

wherein at least one, communicated to a central portion in the axial direction of said stator iron core, of said plurality of ventilating passages constitutes part of said second ventilating circuit; and

said coolers provided in said first ventilating circuit and said coolers in said second ventilating circuit are opposed to each other with a rotating shaft put therebetween.

10. A rotating electric machine according to any one of claims 1 to 9, wherein said stator iron core has a plurality of ventilating ducts which continuously extend in the radial direction and which are arranged in the axial direction; and

axial intervals of those, positioned at said central portion in the axial direction of said stator iron core, of said ventilating ducts are smaller than axial intervals of those, positioned at the other portion of said stator iron core, of said ventilating ducts.

- 58 -

11. A rotating electric machine according to any one of claims 3 to 9, wherein said stator iron core has a plurality of ventilating ducts which continuously extend in the radial direction and which are arranged in the axial direction; and

axial intervals between those, constituting part of said second ventilating circuit, of said ventilating ducts are smaller than axial intervals between those, constituting part of said second ventilating circuit, of said ventilating ducts.

12. A method of cooling a rotating electric machine, comprising the steps of:

introducing a boosted coolant on the outer peripheral side of a stator iron core;

cooling the coolant thus introduced; and

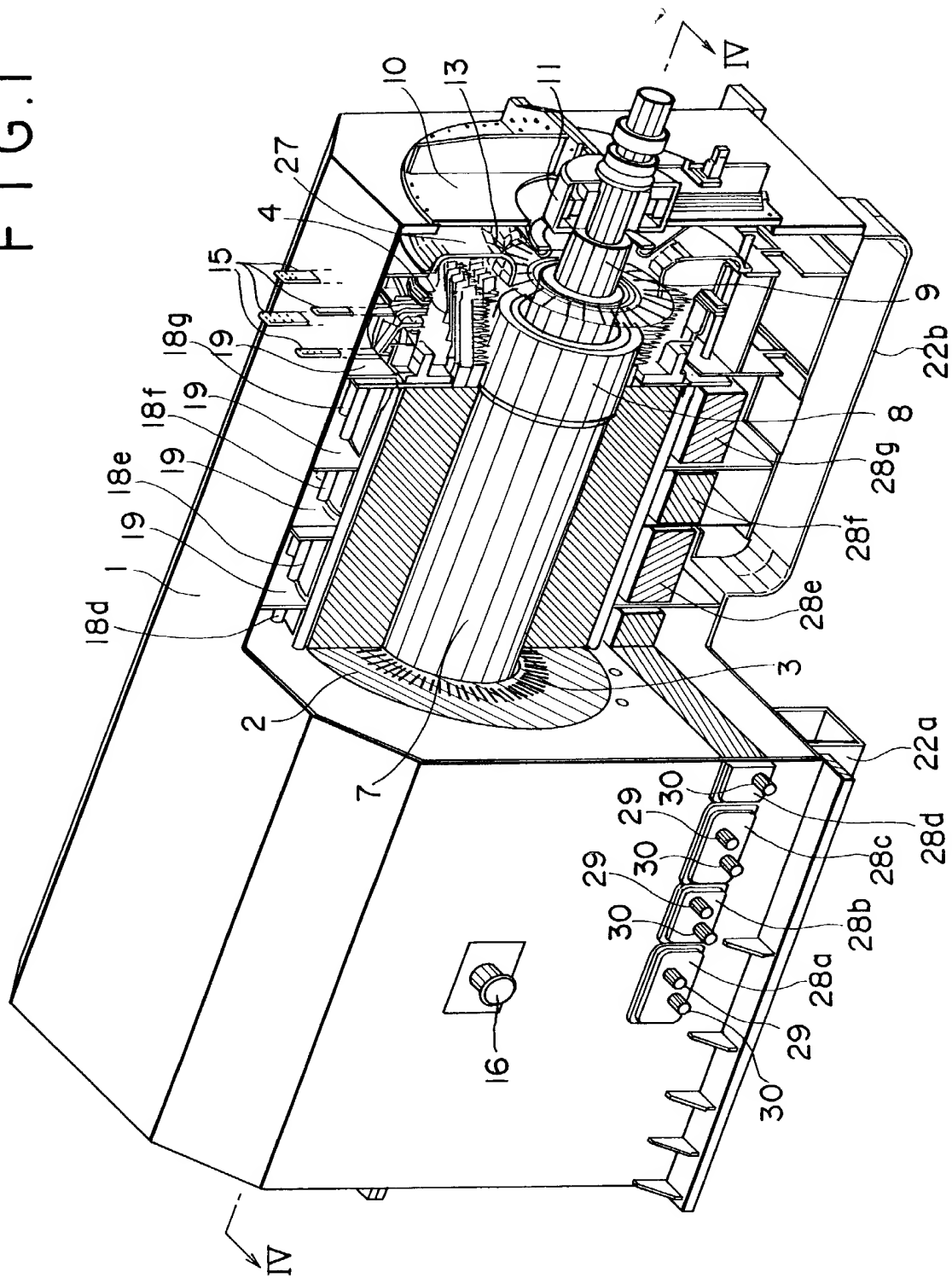
allowing the coolant thus cooled to flow at least to a central portion in the axial direction of the stator iron core in the direction from the outer peripheral side to the inner peripheral side of the stator iron core.

- 59 -

ABSTRACT

Disclosed is a rotating electric machine capable of leveling the axial temperature rise distribution in the machine by supplying a coolant sufficiently cooled to a central portion in the axial direction of an iron core which is most distant from each of the axial ends of the iron core. A plurality of ventilating passages 18, which continuously extend in the peripheral direction, are provided in the axial direction between a stator frame 1 and a stator iron core 2, and coolers 28 are provided in the ventilating passages 18. A coolant boosted by a booster is cooled by the coolers 28 and is allowed to flow to a central portion in the axial direction of the stator iron core 2 in the direction from the outer peripheral side to the inner peripheral side of the stator iron core 2 via ventilating passages 15, communicated to the central portion in the axial direction of the stator iron core 2, of the ventilating passages 18.

FIG. 1



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2/11

FIG. 2

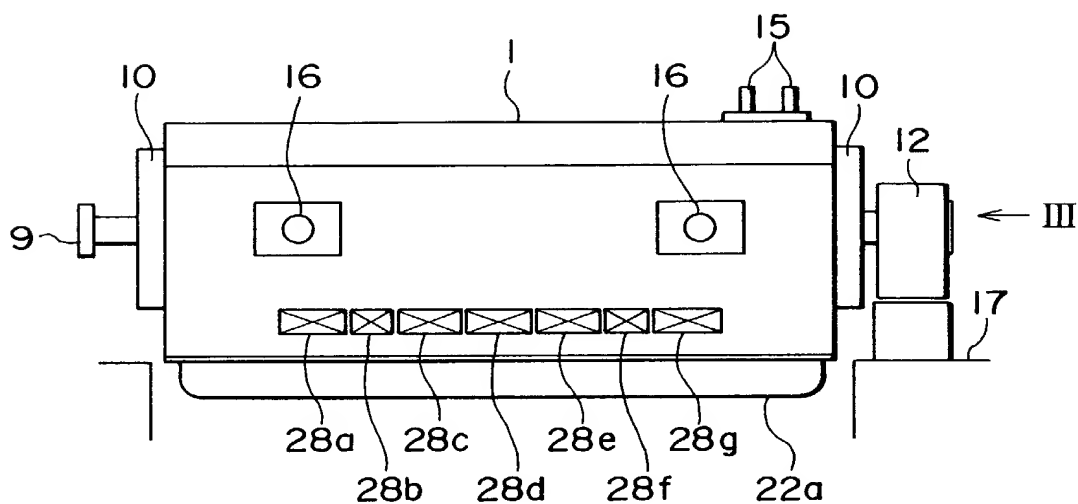


FIG. 3

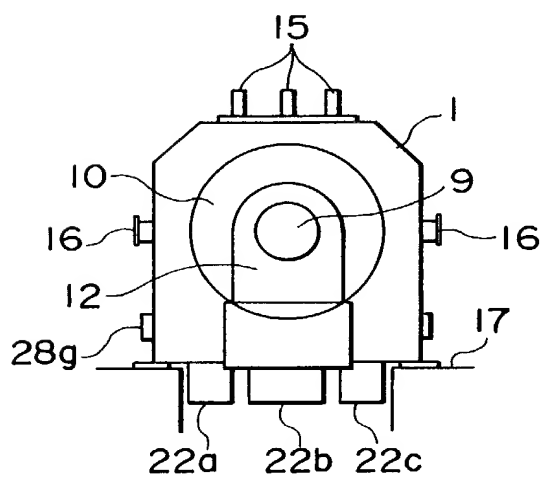


FIG. 4

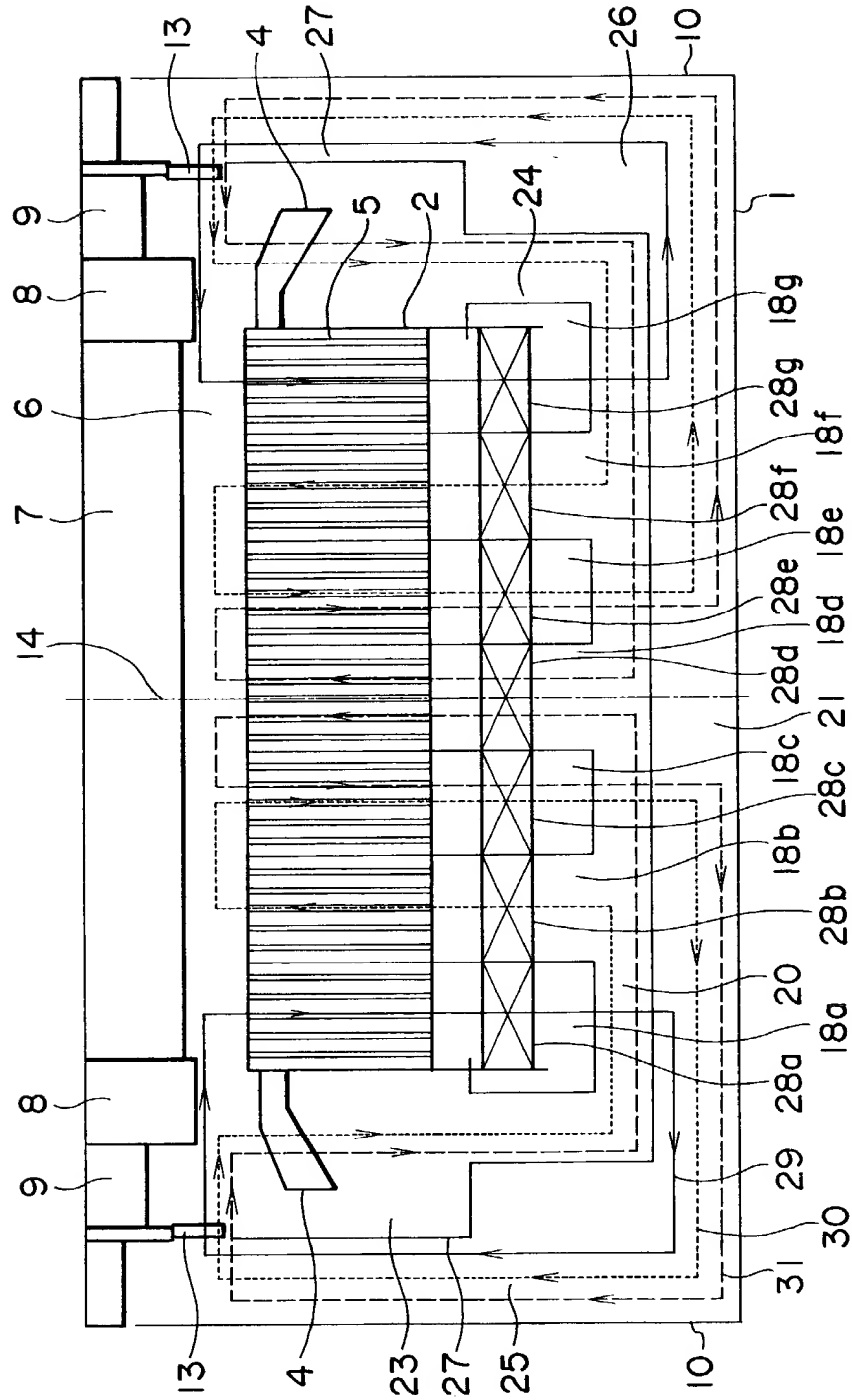


FIG. 5

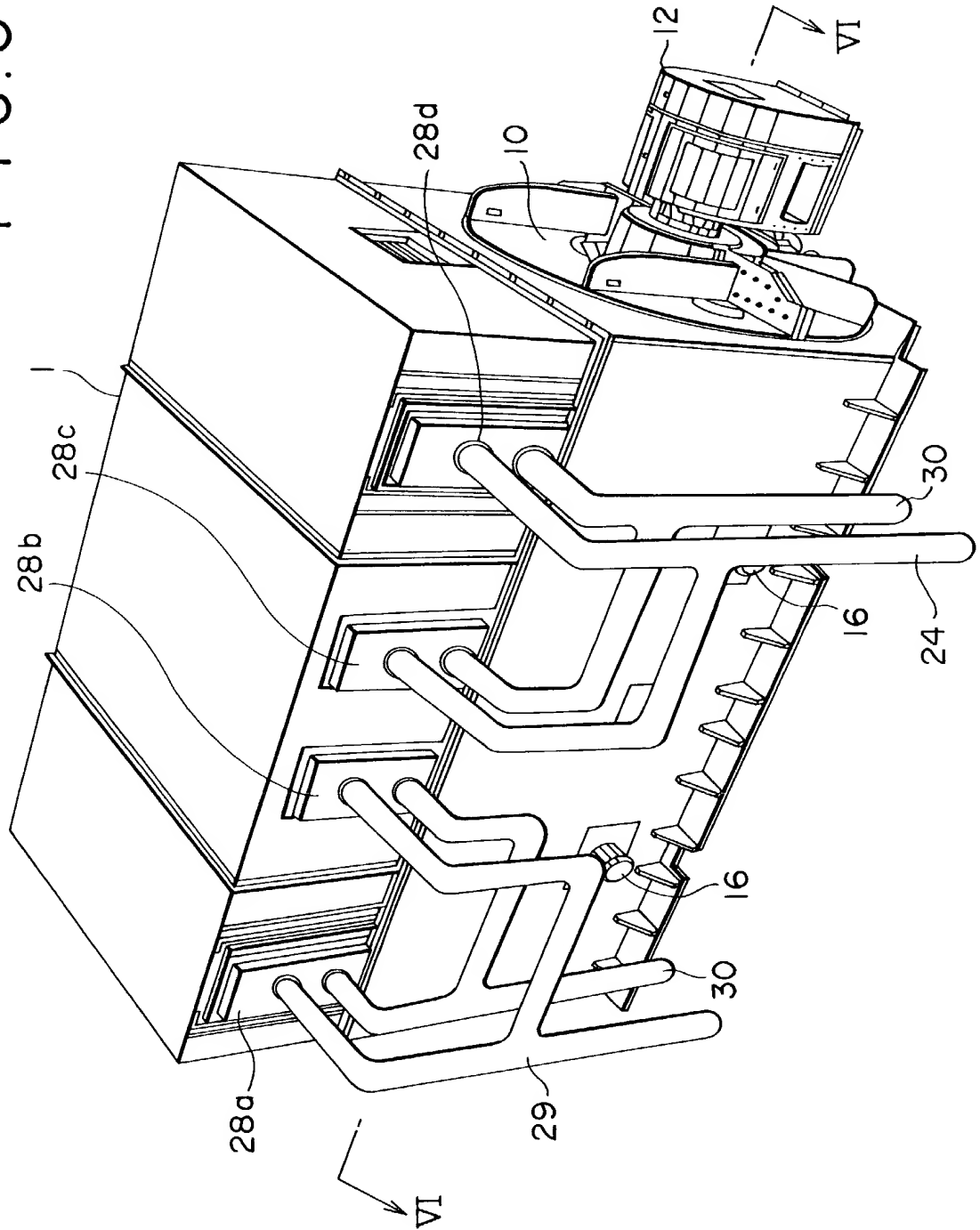
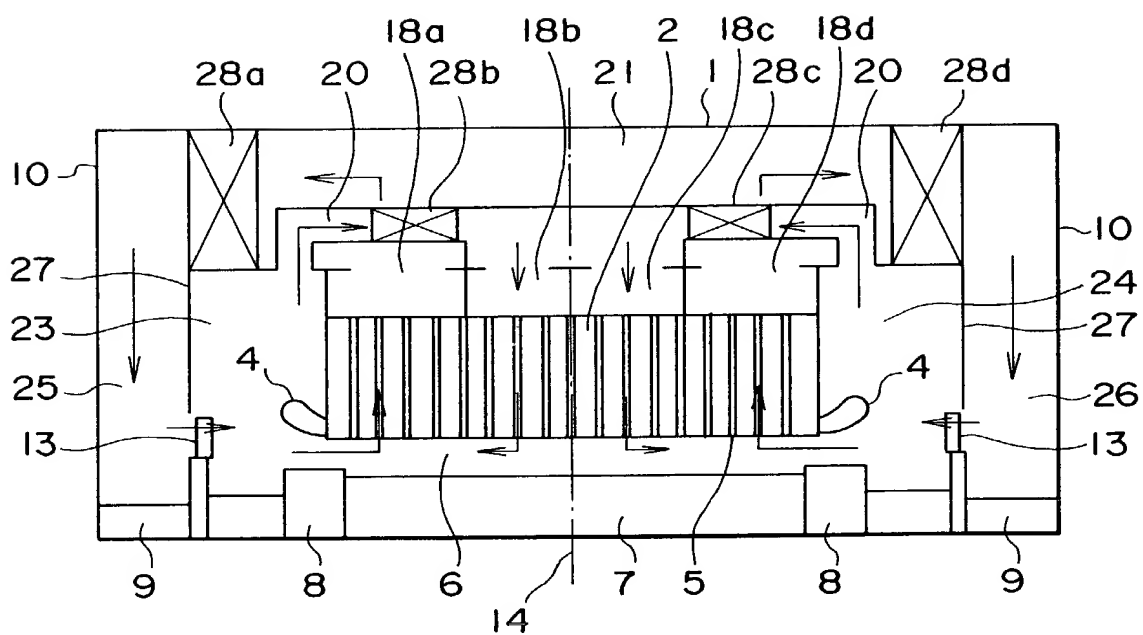


FIG. 6



6/11

FIG. 7

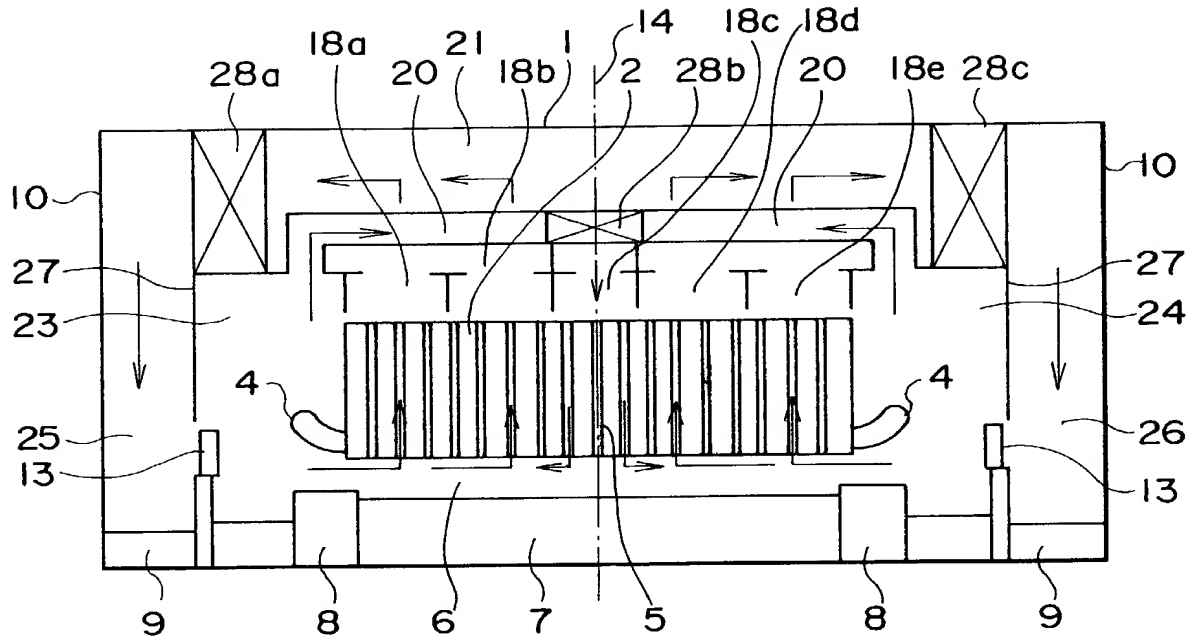


FIG. 8

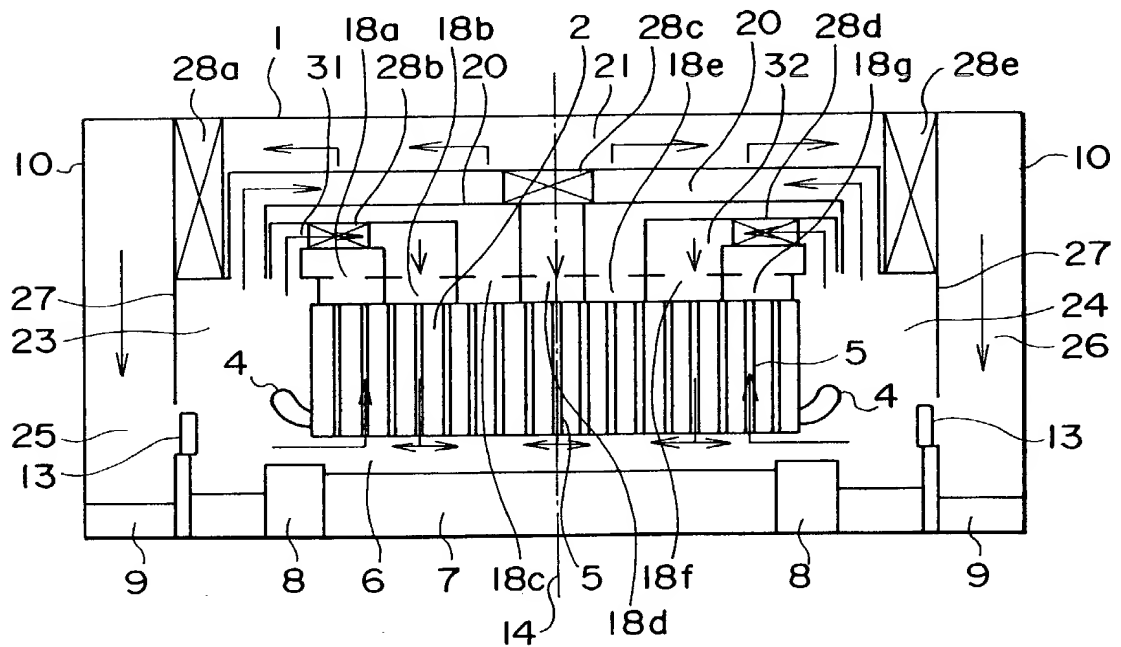
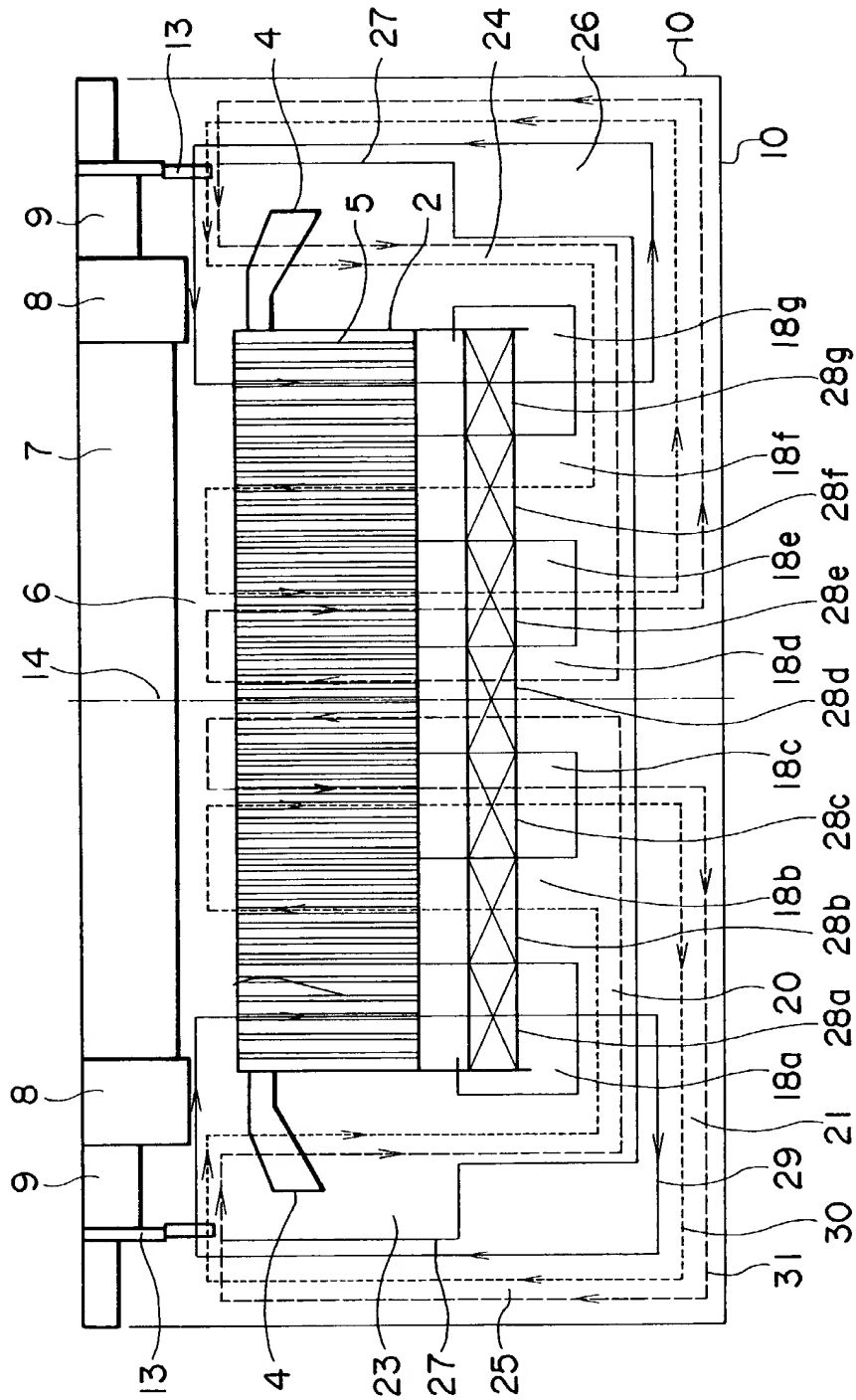


FIG. 9



8/11

FIG. 10

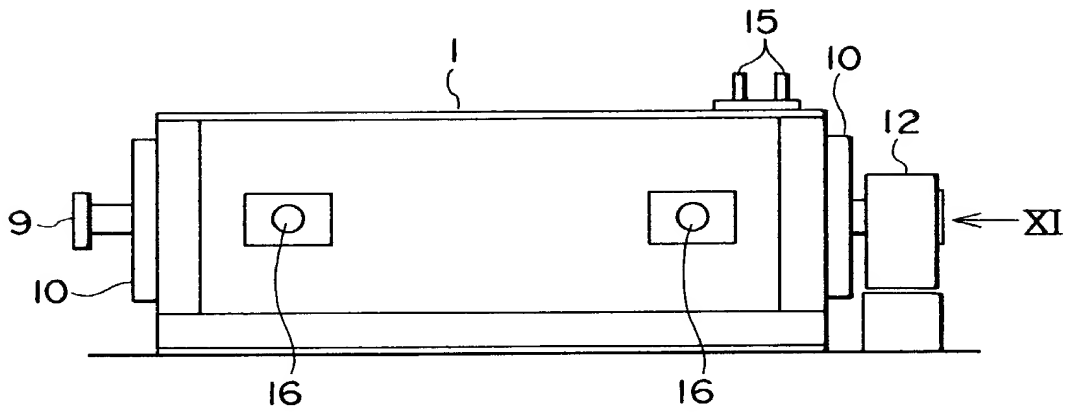


FIG. 11

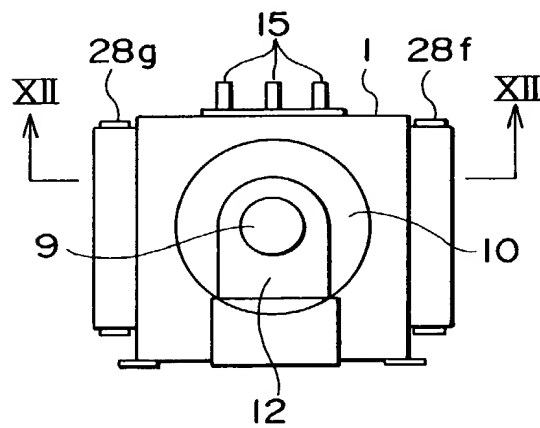


FIG. 12

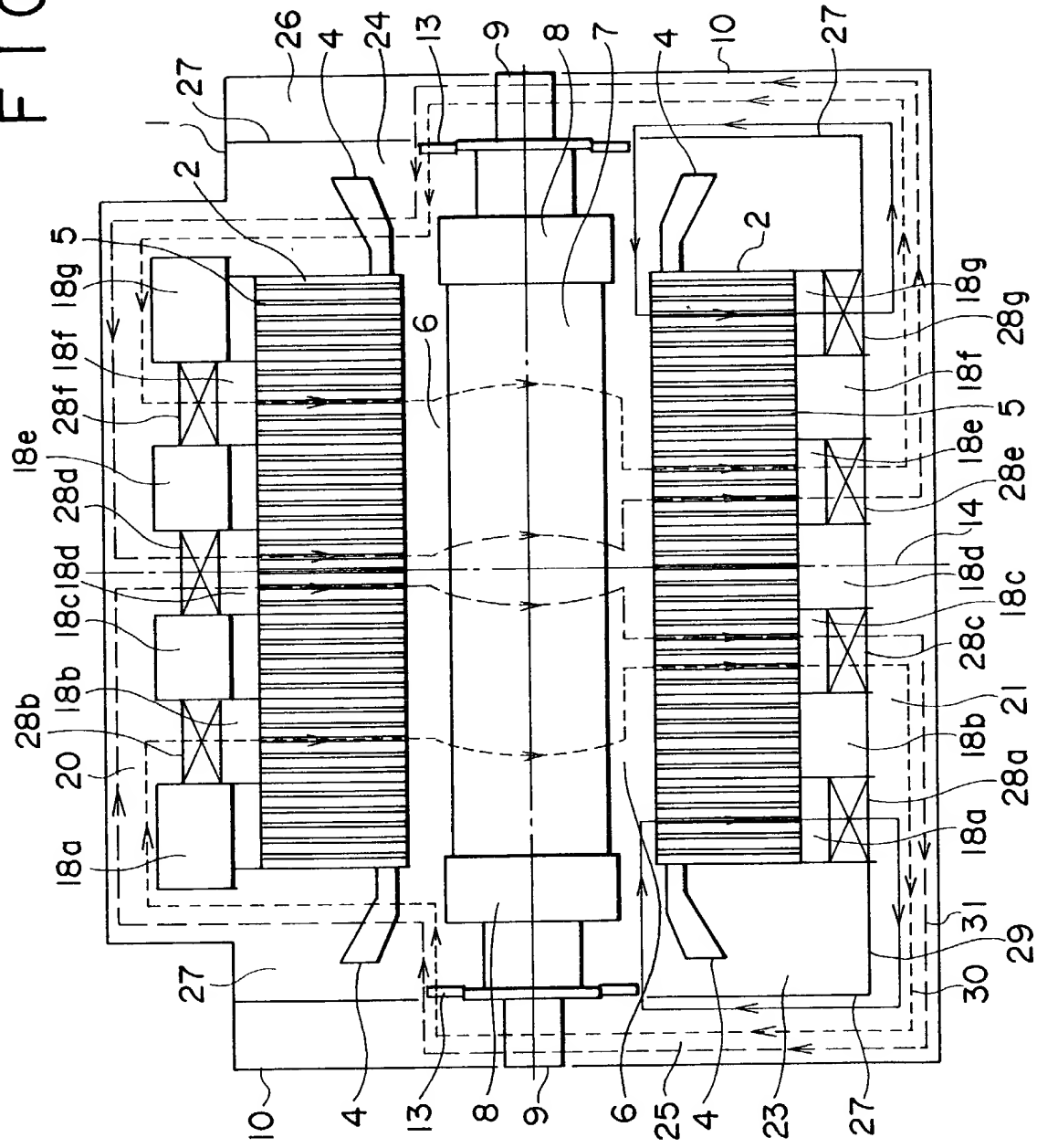
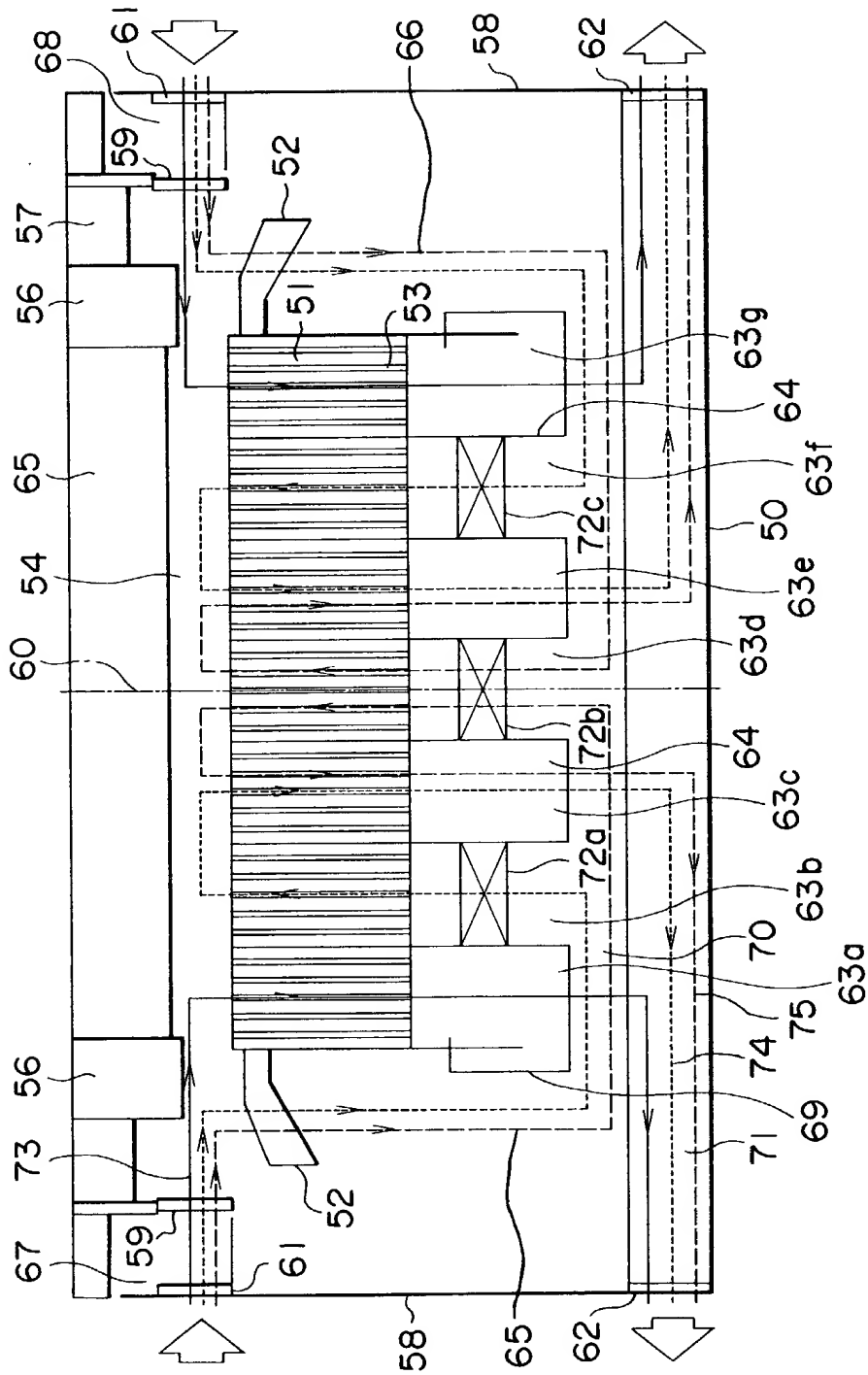
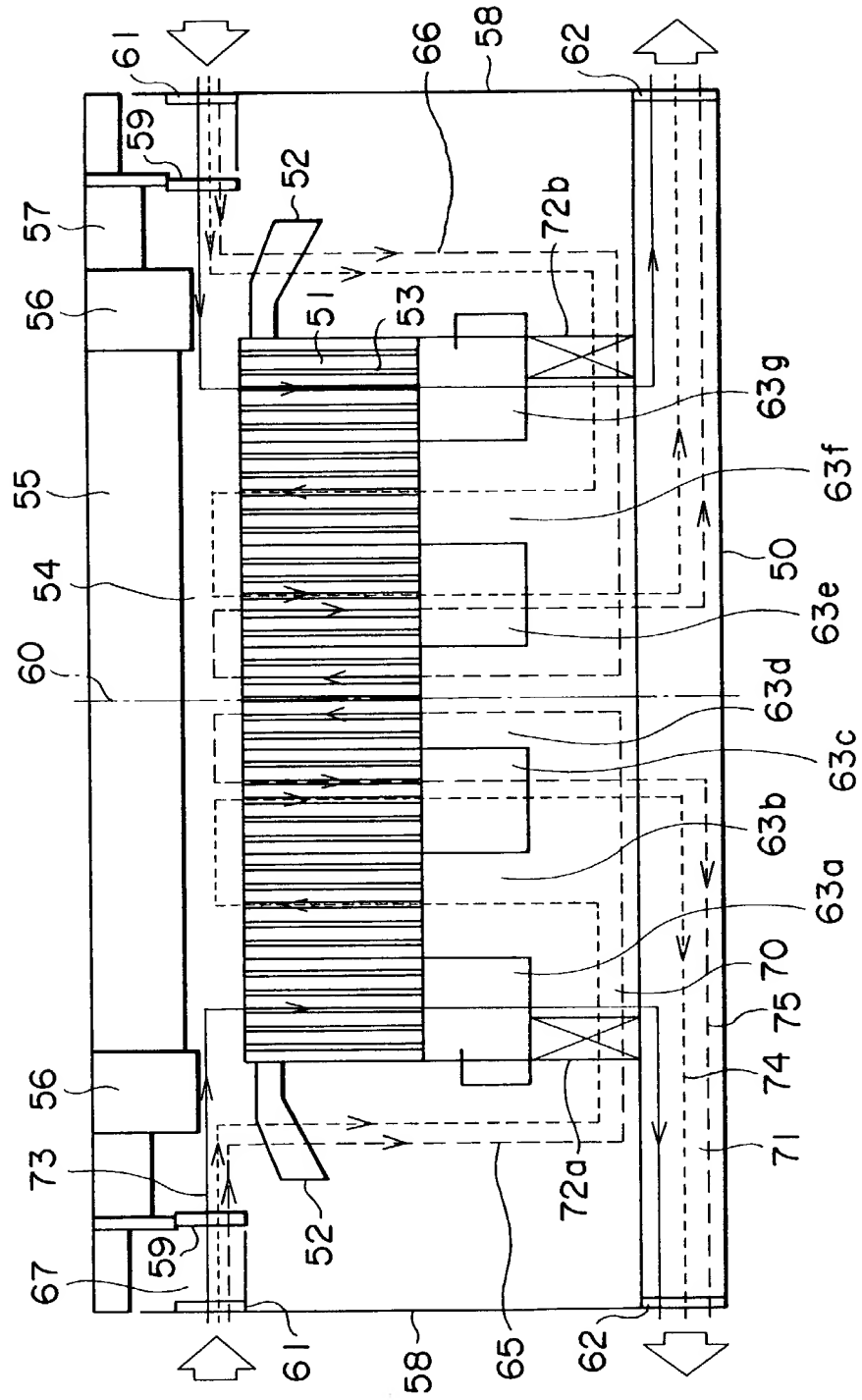


FIG.13



11/11

FIG. 14



DECLARATION AND POWER OF ATTORNEY FILED WITH U.S. DESIGNATED OFFICE UNDER 35 U.S.C. 371(c)(4)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

ROTATING ELECTRIC MACHINE AND COOLING METHOD THEREOF

the specification of which was filed as PCT International Application No. PCT/JP99/04790
 filed September 3, 1999 and was amended on _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)**Priority Claimed**

_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status: patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status: patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status: patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status: patented, pending, abandoned)

I hereby appoint as principal attorneys; Donald R. Antonelli, Reg. No. 20,296; David T. Terry, Reg. No. 20,178; Melvin Kraus, Reg. No. 22,466; Stanley A. Wal, Reg. No. 26,432; William I. Solomon, Reg. No. 28,565; Gregory E. Montone, Reg. No. 28,141; Ronald J. Shore, Reg. No. 28,577; Donald E. Stout, Reg. No. 26,422; Alan E. Schiavelli, Reg. No. 32,087 and James N. Dresser, Reg. No. 22,973 to prosecute and transact all business connected with this application and any related United States application and international applications. Please direct all communications to the following address:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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